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U. S. Circuit Court of Appeals

— SECOND CIRCUIT —

CASES AND BRIEFS

1929 Term

55'

Vol. 1738

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1738

UNITED STATES CIRCUIT COURT OF APPEALS FOR THE SECOND CIRCUIT.

POWER SPECIALTY COMPANY,

Plaintiff-Appellee,

—AGAINST—

THE CONNECTICUT LIGHT & POWER COMPANY

AND

B. F. STURTEVANT COMPANY,

Defendants-Appellants.

TRANSCRIPT OF RECORD.

ON APPEAL FROM THE UNITED STATES DISTRICT COURT, FOR THE DISTRICT OF CONNECTICUT.

L. H. Lane, Law Printer, 221 High Street, Boston

CIRCUIT COURT OF APPEALS
FILED
NOV 28 1928
CLERK

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District Court of the United States, 1

DISTRICT OF CONNECTICUT.

IN EQUITY.

No. 1869.

POWER SPECIALTY COMPANY, PLAINTIFF,

v.

THE CONNECTICUT LIGHT & POWER COMPANY

AND

B. F. STURTEVANT COMPANY, DEFENDANTS.

2

CITATION ON APPEAL.

UNITED STATES OF AMERICA, SS.

THE PRESIDENT OF THE UNITED STATES,

To POWER SPECIALTY COMPANY, *a corporation organized and existing under the laws of the State of New York and a citizen and resident of the State of New York,*

GREETING:

You are hereby cited and admonished to be and appear in the United States Circuit Court of Appeals for the Second Circuit, in the City of New York, New York, on the twenty-seventh day of October next, pursuant to an appeal duly obtained from a decree of the District Court of the United States for the District of Connecticut, signed, filed and entered on the twenty-sixth day of September, 1928, in that certain suit being in Equity 1869, wherein the Connecticut Light & Power Company, a corporation organized and existing under the laws of the State of Connecticut and a citizen and resident of the State of Connecticut, and B. F. Sturtevant Company, a corporation organized and existing under the laws of the Commonwealth of Massachusetts, and a citizen and resident

3

4 of the Commonwealth of Massachusetts, are appellants and you are appellee, to show cause, if any there be, why the said decree entered against the said appellants should not be corrected, and why speedy justice should not be done to the parties in that behalf.

EDWIN S. THOMAS,
United States District Judge for the District of Connecticut.

Norwalk, September 29, 1928.

Service accepted, October 1, 1928.

HENRY F. PARMELEE.

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5 DISTRICT COURT OF THE UNITED STATES,
DISTRICT OF CONNECTICUT.
IN EQUITY.

No. 1869.

POWER SPECIALTY COMPANY, PLAINTIFF,
v.
THE CONNECTICUT LIGHT & POWER COMPANY,
DEFENDANT.

BILL OF COMPLAINT.
[Filed September 22, 1926.]

Power Specialty Company, a corporation organized and existing under and by virtue of the laws of the State of New
6 York, and having its principal office in the City of New York in said State, brings this, its bill of complaint, against The Connecticut Light & Power Company, a corporation of the State of Connecticut, having its principal office in the City of Waterbury, New Haven County, State of Connecticut, and a citizen of said State, and respectfully shows unto this Honorable Court as follows:

1. That this is a suit for infringement of United States Letters Patent and this bill prays for equitable relief; that the plaintiff is a citizen and inhabitant of the State of New

York, and the defendant is a citizen and inhabitant of the 7
State of Connecticut, and has therein committed acts of infringement hereinafter complained of; and that the matter in controversy exceeds the sum of three thousand dollars ($3,000) in value, exclusive of interest and costs.

2. That heretofore, and prior to the first day of July 1922, John E. Bell of Brooklyn, New York, was the original, first and sole inventor of a certain new and useful improvement in steam generating plants, not known or used in this country and not patented or described in any printed publication in this or any foreign country before his said invention or discovery thereof, and not more than two years prior to his hereinafter recited application for patent therefor, and not in 8
public use or on sale for more than two years prior to his application for patent therefor and not abandoned; and that no application for a foreign patent for said invention was filed more than twelve months prior to the filing of his application in the United States, and that, being such original, first and sole inventor, the said John E. Bell on the first day of July 1922 made application in due form of law to the Commissioner of Patents for Letters Patent of the United States.

3. That by a valid written assignment duly recorded in the United States Patent Office the entire right, title and interest in and to said invention and any Letters Patent which 9
should be granted upon said application became vested in the plaintiff, Power Specialty Company, as by said assignment, here in court to be produced, will more fully and at large appear.

4. That thereupon such proceedings were had that upon the fifteenth day of December 1925, Letters Patent No. 1,565,305 were granted to the plaintiff, Power Specialty Company, as assignee of said John E. Bell, in conformity with the requirements of the statutes in such cases made and pro-

10 vided, under the seal of the Patent Office, and having the name of the Commissioner of Patents printed thereon and attested by one of the law examiners of the Patent Office duly designated by the Commissioner of Patents; and that said Letters Patent, in their terms, granted to the plaintiff, Power Specialty Company, its successors and assigns, for the term of seventeen years from the said fifteenth day of December 1925 the exclusive right to make, use and vend throughout the United States and territories thereof, the invention therein described and claimed, referring to its specification for the particulars thereof, as by said Letters Patent or a duly authenticated copy thereof, here in court to be produced,
11 will more fully and at large appear.

5. A copy of the specifications of said Letters Patent is filed herewith as an exhibit and is to be taken as part hereof.

6. That by virtue of the premises, the plaintiff, Power Specialty Company, became and now is the owner of the exclusive right, title and interest in and to the said Letters Patent, and in and to the inventions claimed therein.

7. That the plaintiff has invested and expanded large sums of money and has been to great trouble in and about the inventions of said Letters Patent, and for the purpose of introducing the same into use and making the same profitable to the plaintiff and to the public; that said inventions have been
12 put into extensive and successful commercial use by the plaintiff, and have been received with great favor by the users of steam generating plants, and have been and are of great benefit and advantage to the plaintiff and to the public; that the public has generally acknowledged and acquiesced in the aforesaid rights of the plaintiff; and that the plaintiff believes that it will realize and receive large gains and profits therefrom if infringements by said defendant and its confederates shall be prevented.

8. That said defendant has had due and timely notice of

its said infringements and of the rights of the plaintiff and 13
the premises, but has disregarded said notice and refused to desist from its infringement and still continues so to do.

9. That, as the plaintiff is informed and believes, said defendant without license of the plaintiff, and against the plaintiff's will, and in violation of the plaintiff's rights, has since the fifteenth day of December 1925, made, and caused to be made and used, and is now making and causing to be made and using, and is threatening to continue to make and to cause to be made and to use steam generating plants within the District of Connecticut which embody in material and substantial parts thereof the improvements set forth in said
Letters Patent No. 1,565,305, all in defiance of the rights 14
acquired by and secured by the plaintiff as aforesaid, and to the plaintiff's great and irreparable loss and injury, and by which the plaintiff has been and still is being deprived of great gain and profits which it might and otherwise would have obtained but which have been received and enjoyed and are being received and enjoyed by said defendant, by and through the aforesaid unlawful acts and doings.

10. That, as plaintiff is informed and believes, said defendant has made and realized large profits and advantages from said infringements, but to what extent, and how much exactly, plaintiff does not know, and prays discovery thereof,
and plaintiff says that the use of said inventions by said 15
defendant, and its preparation for and avowed determination to continue to use the same, and its other aforesaid unlawful acts in disregard and in defiance of the rights of the plaintiff, have the effect to encourage and induce others to venture to infringe said Letters Patent in disregard of the plaintiff's rights.

Plaintiff therefore prays:

1st. That the said defendant, according to the best and utmost of its knowledge, remembrance, information and be-

16 lief, shall make, to the matters and things hereinbefore stated and charged, full, true, direct and perfect answer, not, however, under oath, which is hereby waived.

2d. That a writ of subpoena may issue, directed to the said defendant, The Connecticut Light & Power Company, commanding it on a certain day therein to be named to appear and answer unto this bill of complaint, and to abide and perform such order and decree in the premises as to this court shall seem meet and may be required by the principles of equity and good conscience.

3d. That the said defendant may be decreed to account for and pay to the plaintiff the profits or income thus unlawfully
17 derived from the violation of the plaintiff's rights, and that upon the entering of the decree against the defendant for infringement, your Honors may proceed to assess, or cause to be assessed under your direction, as well as the defendant's said unlawful profits or income, as also in addition the damages sustained by the plaintiff by reason of defendant's said unlawful acts, and that your Honors may increase the actual damages so assessed to a sum equal to three times the amount of such assessment, under the circumstances of the willful and unjust nature of the said acts.

4th. That a writ of injunction may be issued from and under the seal of this court perpetually enjoining and re-
18 straining said defendant, its clerks, attorneys, servants, agents and workmen from any further manufacture, sale or use in any manner of the said patented improvement or any part thereof, in violation of plaintiff's rights.

5th. That a provisional or preliminary injunction be issued, restraining the defendant, its clerks, attorneys, servants, agents and workmen to the same purpose, tenor and effect hereinbefore prayed for in regard to said perpetual injunction.

6th. That such other and further relief may be granted

and decreed to the plaintiff as the equity of the case may 19
require and to your Honors may seem meet.

POWER SPECIALTY COMPANY,
by L. B. NUTTING, *President.*

HENRY F. PARMELEE,
Solicitor for Plaintiff,
865 Chapel St., New Haven, Connecticut.

JOHN E. HUBBELL,
of Counsel,

STATE OF NEW YORK,
COUNTY OF NEW YORK, SS.

Before me personally appeared Louis B. Nutting, who, 20
being duly sworn, deposes and says that he is one of the officers, namely the president, of Power Specialty Company, the said plaintiff; that he has read the foregoing bill of complaint and knows the contents thereof, and that the same is true of his own knowledge, except as to the matters therein stated on information and belief, and as to those matters he verily believes it to be true; and further, deponent says that he verily believes that the said John E. Bell was the original, first and sole inventor of the inventions described and claimed in the Letters Patent named in said bill, and that the plaintiff's title to the latter's patent in suit is as set forth
in said bill. 21

LOUIS B. NUTTING.

Sworn to and subscribed before me this seventeenth day of September, 1926.

AGNES T. KENNEY,
[SEAL] *Notary Public, Richmond Co.*
Certificate filed N. Y. County No. 312,
N. Y. County Register No. 8263,
Richmond Co. Register.
Commission expires March 30, 1928.

22 [Title omitted.]

ANSWER OF THE CONNECTICUT LIGHT & POWER COMPANY, DEFENDANT, TO THE BILL OF COMPLAINT OF POWER SPECIALTY COMPANY.

[Filed November 12, 1926.]

The defendant now and at all times hereafter saving and reserving to itself all and all manner of benefit or advantage of exception or otherwise that can or may be had or taken to the many errors, uncertainties and imperfections in the said bill contained, for answer thereto, or to so much thereof as this defendant is advised is material or necessary for it to make answer unto, answering, says:

23 1. The defendant is not advised, save by the bill of complaint, whether the plaintiff is a corporation existing under the laws of the State of New York and therefore denies the same; the defendant admits that it is a corporation organized and existing under the laws of the State of Connecticut, and is a resident of said state. The defendant denies that it has committed acts of infringement within the State of Connecticut or elsewhere within the United States.

2. The defendant admits that Letters Patent of the United States No. 1,565,305 were granted on the fifteenth day of December, 1925 from the Patent Office of the United States to the plaintiff, Power Specialty Company, but denies, on in-
24 formation and belief, that John E. Bell was the original, first and sole inventor of the alleged invention or improvement in steam generating plants for which said Letters Patent No. 1,565,305 purport to have been granted, or of any material or substantial part thereof, and avers, upon information and belief, that the said Bell was not the original, first and sole inventor of said alleged invention or improvements, and denies that the same had not been known or used by others in this country before his invention or discovery thereof, or patented or described in any printed publication in this or

any foreign country before his invention or discovery thereof 25
or more than two years prior to his application for said Letters Patent, and denies that said invention had not been in public use or on sale in this country for more than two years prior to the said application, and denies that said alleged invention had not first been patented or caused to be patented by him or his legal representatives or assigns in any foreign country on an application filed more than twelve months prior to the filing in this country of said application for said Letters Patent, and denies that said invention had not been abandoned, and avers, upon information and belief, that said invention had been abandoned.

3. The defendant, further answering, admits that the said 26
Bell filed an application for Letters Patent of the United States for said alleged invention on or about the first day of July 1922, but denies, upon information and belief, that said application was in due form of law, or that due proceedings were had upon said application.

4. The defendant is not informed, save by said bill of complaint, whether by a valid written assignment, duly recorded in the United States Patent Office, the entire right, title, and interest in and to said invention and any Letters Patent which should be granted thereon became vested in the plaintiff, Power Specialty Company, and, therefore, denies the same; the defendant admits said Letters Patent No. 1,565,305 were 27
granted to said Power Specialty Company, but denies that there was thereby granted and secured to the plaintiff and its successors and assigns, for the term of seventeen years from and after the date of said Letters Patent, the full and exclusive right and liberty of making, using, and vending throughout the United States and territories thereof the alleged invention or improvements set forth in said Letters Patent.

5. The defendant is not advised, save by the bill of com-

28 plaint, whether the plaintiff has invested and expended large sums of money and has been put to great trouble in and about the alleged inventions and improvements attempted to be patented in said Letters Patent for the purpose of introducing the same into use and making the same profitable to itself and to the public, or whether said inventions have been put into extended and commercial use by the plaintiff, or have been received with favor by the users of steam generating plants, or have been and are of great benefit and advantage to the plaintiff and to the public, and therefore denies the same.

6. The defendant, upon information and belief, denies that
29 the public has generally acknowledged and acquiesced in the alleged rights of the plaintiff and denies that the defendant has caused or deprived, or will cause or deprive, the plaintiff from large or any gains or profits from said alleged rights.

7. The defendant denies that it has had due and timely, or any, notice from plaintiff of the latter's alleged rights, and denies that it has disregarded any notice, or has infringed, or continues to infringe such rights.

8. The defendant denies that it has, without license of the plaintiff and against the plaintiff's will or in violation of the plaintiff's alleged rights under said Letters Patent, since the
30 fifteenth day of December, 1925, made or caused to be made and used, or is now making or causing to be made and used, or is threatening to continue to make or cause to be made or used, steam generator plants within the district of Connecticut or elsewhere within the United States, which embodied or embody in substantial and material parts thereof the alleged improvements set forth in said Letters Patent No. 1,565,305, in defiance of the plaintiff's alleged rights or to the plaintiff's great or irreparable loss or damage. The defendant denies that the plaintiff has been and still is being deprived of great or any gain or profits which it might or

otherwise would have obtained, and which have been re- 31
ceived and enjoyed and are being received and enjoyed by the defendant by and through any unlawful acts or doings by it.

9. The defendant denies that it has made or realized large or any profits or advantages by any acts in infringement of the plaintiff's alleged rights under said Letters Patent, and denies that it has used the inventions patented in and by said Letters Patent or is prepared and determined to use the same, or that any of its acts and doings have had the effect of encouraging and inducing others to infringe said Letters Patent and to disregard any rights of the plaintiff thereunder.

10. The defendant avers, upon information and belief, that 32
the alleged invention or improvement or material or substantial parts thereof described and claimed as new in said Letters Patent No. 1,565,305, and attempted to be patented thereby, were prior to the supposed invention or discovery thereof by said Bell, or more than two years prior to his application for a patent thereon, patented in and by the following specified Letters Patent of the United States and described in the specification thereunder specifically belonging, printed and published at the United States Patent Office at Washington, D. C., to wit:

590,830, L. M. C. Delaunay-Belleville, September 28, 1897. 33
607,033, J. E. Gresty, July 12, 1898.
666,537, M. Levi & C. Radonicich, January 22, 1901.
712,490, F. Blossom & J. D. E. Duncan, November 4, 1902.
744,323, E. H. Foster, November 17, 1903.
767,187, R. Wadham, August 9, 1904.
886,516, R. Kablitz, May 5, 1908.
920,591, H. Lemp, May 4, 1909.
963,732, E. H. Foster, July 5, 1910.
1,037,313, J. Primrose, September 3, 1912.
1,107,313, G. H. Klump & J. E. Houston, August 18, 1914.

34 1,239,377, E. H. Foster, September 4, 1917.
1,281,016, D. S. Jacobus, October 8, 1918.
1,282,851, W. F. Keenan & D. D. Thomas, October 29, 1918.
1,308,138, C. D. Young, July 1, 1919.

And in and by the following specified Letters Patent of Great Britain, printed and published at the British Patent Office, London, England, to wit:

16,730, James Bartlett, July 29, 1904.

24,162, Societe J. & A. Niclausee, December 16, 1914.

And in and by the following Letters Patent of France, printed and published at the French Patent Office, Paris, France, to wit:

35 432,342, Mme. veuve Frederic Fouche, filed July 19, 1911, granted October 3, 1911.

11. The defendant avers, upon information and belief, that the alleged invention or improvement or material or substantial parts thereof described and claimed as new in said Letters Patent No. 1,565,305, and attempted to be patented thereby, were prior to the supposed invention or discovery thereof by said Bell, or more than two years prior to his application for a patent thereon, described and illustrated in printed publications as follows:

Elements of Heat-Power Engineering, by C. F. Hirshfeld and William N. Barnard, published by John
36 Wiley & Sons, Inc., 1915.

The Book of the Economizer, published by The Green Fuel Economizer Company, copyrighted 1907.

Bulletin 163, published by B. F. Sturtevant Company, March 1909.

Green's Economizers, published by Green Fuel Economizers, copyright 1912.

Sturtevant Bulletins Nos. 161 and 162, published by B. F. Sturtevant Company, January 1909 and December 1909, respectively.

Green's Improved Patent Fuel Economizer for steam boilers, published by The Green Fuel Economizer Company, copyrighted 1904. 37

12. The defendant avers, upon information and belief, that the alleged invention or improvement, or material or substantial parts thereof, described and claimed as new in said Letters Patent No. 1,565,305, and attempted to be patented thereby, were, prior to the said invention or discovery thereof by the said Bell, invented or known or used by others in this country, and were, more than two years prior to his said application for patent, in public use or on sale in this country, and among those who had invented, or who had such prior knowledge or use, or who had made such public 38 use or sale of the same, are the following, whose present residences and the places where they had such prior knowledge or use, or where such public use or sale occurred, are as follows:

Ernest H. Foster of Dougan Hills, New York, at said Dougan Hills, New York, and elsewhere in the United States;

David S. Jacobus of Jersey City, New Jersey, at Jersey City, New Jersey, and elsewhere in the United States;

Charles D. Young of Altoona, Pennsylvania, at said Altoona, Pennsylvania, and elsewhere in the United States; 39

Walter F. Keenan of New York, New York, at said New York and elsewhere in the United States;

David D. Thomas of Baltimore, Maryland, and elsewhere in the United States;

B. F. Sturtevant Company of Hyde Park, Boston, Massachusetts, at said Hyde Park, Boston, Massachusetts, Lawrence, Massachusetts, Worcester, Massa-

40 chusetts, Hamilton, Ohio, and elsewhere in the United States;

Ernest B. Freeman of Cohasset, Massachusetts, at Hyde Park, Boston, Massachusetts, Worcester, Massachusetts, Lawrence, Massachusetts, Hamilton, Ohio, and elsewhere in the United States;

Merton S. Leonard of Hyde Park, Boston, Massachusetts, at said Hyde Park, Boston, Massachusetts, Worcester, Massachusetts, Lawrence, Massachusetts, Hamilton, Ohio, and elsewhere in the United States;

Power Specialty Company of New York, New York, at
41 said New York, New York, and elsewhere in the United States;

Gardner C. Derry of Sharon, Massachnsetts, at Hyde Park, Boston, Massachusetts;

Champion Coated Paper Company of Hamilton, Ohio, at said Hamilton, Ohio, and elsewhere in the United States;

Wood Worsted Mills of Lawrence, Massachusetts, at said Lawrence, Massachusetts, and elsewhere in the United States;

American Steel and Wire Company of Worcester, Massachusetts, at said Worcester, Massachusetts, and
42 elsewhere in the United States;

Green Fuel Economizer Company at Matteawan, New York, at said Matteawan, New York, Philadelphia, Pennsylvania, and elsewhere in the United States;

John F. Daggett of New York, New York, at said New York, New York, Worcester, Massachusetts, Lawrence, Massachusetts, Hamilton, Ohio, and elsewhere in the United States;

Arthur H. Blackburn of Worcester, Massachusetts, at

Philadelphia, Pennsylvania, and elsewhere in the United States; 43

and by others whose names and addresses are not now known, but as soon as ascertained this defendant will ask leave to add to this answer.

13. And the defendant avers, upon information and belief, that the said alleged invention or improvement, or material and substantial parts thereof described and claimed as new in said Letters Patent No. 1,565,305, and attempted to be patented thereby, did not, at the time of the alleged invention thereof by the said Bell, exhibit or show any substantial variation or change from what belonged to the state of the art as it existed at that time, and was without patentable novelty or invention, and did not require the exercise of the inventive faculty at the date of the said alleged invention, and did not constitute subject-matter of a quality proper to be secured by the grant of Letters Patent within the meaning and intent of the statutes of the United States relating to the grant of patents for inventions. 44

14. And the defendant further answering avers, upon information and belief, that said Letters Patent is invalid because it does not describe said invention in such full, clear, concise and exact terms as to enable any person skilled in the art or science to which it appertains, or to which it is most nearly connected, to make, construct, compound and use the same, and does not explain the principle and the best mode of applying that principle so as to distinguish it from other inventions, and because it does not particularly point out and distinctly claim the improvement or combination claimed as the invention or discovery; but, on the contrary, said specification and claims are uncertain and indefinite. 45

15. The defendant avers that such proceedings were had in the Patent Office upon the application for said Letters Patent No. 1,565,305, that the plaintiff is now estopped to con-

46 tend that the construction complained of is an infringement of said Letters Patent.

16. And the defendant denies that the plaintiff has any right to an injunction, provisional or perpetual, against it, or any right to an accounting as prayed for in said bill of complaint, or to any damages, and denies that by reason of any matter or thing set forth by said bill of complaint, and not herein specifically denied, the plaintiff has any right or equity to have any relief prayed for in said bill of complaint, or any part thereof, against the defendant; without this, that there is any other matter, cause or thing in the said plaintiff's bill of complaint contained material or necessary for the defend-
47 ant to make answer unto, and not herein and hereby well and sufficiently answered, confessed and avoided, traversed or denied, is true to the knowledge and belief of the defendant, all of which matters and things the defendant is ready to aver, maintain and prove as this Honorable Court shall direct, and humbly prays to be hence dismissed with its reasonable costs and charges in its behalf most wrongfully sustained.

THE CONNECTICUT LIGHT & POWER COMPANY,
by WILLIAM E. THOMS,
of CARMODY & THOMS.

---

48 [Title omitted.]

AMENDMENT TO ANSWER.

[Filed May 20, 1927.]

Now comes the defendant and amends its answer in the following particulars:

(a) By adding to the list of United States patents in paragraph 10 the following:

No. 777,083, B. W. Davis, December 13, 1904.
No. 780,565, A. H. Humphrey, January 24, 1905.
No. 1,313,991, Jacobus & Jones, August 26, 1919.

stipulation, and during the pendency of the appeal to be taken 61
by the defendants and until the filing with the clerk of this court of the mandate of the United States Circuit Court of Appeals, the issuance of injunction provided for in the decree of this court entered be, and hereby is, suspended.

EDWIN S. THOMAS,
United States District Judge.

[Title omitted.]

STIPULATION.

[Filed September 26, 1928.]

It is stipulated and agreed by and between the parties to the above-entitled cause as follows: 62

1. The defendants, jointly and severally, agree to serve and file ten days after execution of this stipulation, with the clerk of the United States Circuit Court of Appeals for the Second Circuit, the appeal from the decree of the District Court, and further agree to file forty-five days after the execution of this stipulation the transcript of record on appeal, in the office of the clerk of the Circuit Court of Appeals for the Second Circuit.

2. The B. F. Sturtevant Company agrees to file with the clerk of this court, sixty days after the date of this stipulation, a written statement, verified by one of its officers, setting forth the number and location of all installations of 63
economizers made between December 22, 1925 and the date of the decision of the District Court herein, to wit, August 1, 1928, like that shown in Plaintiff's Exhibits 2, 2-A, 2-B, 2-C and 2-D and/or defined by claim 2 of the patent in suit, also the number of units in each such installation, the square feet of heating surface in each and the total gross sum received by the Sturtevant Company for each such installation.

The B. F. Sturtevant Company agrees to file with the clerk of this court from time to time a similar statement of instal-

64 lations, the contracts for which were concluded prior to August 1, 1928, but which were not completed until after such date. Such statements shall be filed within thirty days from the completion of such installation, the installation being deemed completed when it is accepted and paid for.

3. The B. F. Sturtevant Company agrees to file, during the pendency of the appeal herein, with the clerk of this court, upon the first day of each month during such period, written statements, verified by one of its officers, setting forth the names of the customers and the location of economizers like Plaintiff's Exhibits 2, 2-A, 2-B, 2-C and 2-D and/or defined by claim 2 of the patent in suit, contracts for which were con-
65 cluded subsequent to August 1, 1928, and which were installed, that is, completed, accepted and paid for, during the preceding month; the first of such statements to include all economizers, contracts for which were concluded subsequent to August 1, 1928, and which were installed between August 1, 1928 and the date of such first statement; the last of such statements to include all the economizers, contracts for which were concluded prior to the filing with the clerk of this court of the mandate of the Circuit Court of Appeals, even though some of such installations were not completed until after such date of filing; and the B. F. Sturtevant Company shall have the right to complete, after the date of the filing of the man-
66 date herein, any installation of such economizers, contracts for which were concluded prior to such date.

The B. F. Sturtevant Company agrees to pay to Foster Wheeler Corporation, ten days after the filing of each of such statements referred to in paragraph 3, a sum equal to seven and one-half percent (7½%) of the total sum received by it for each of said installations specified in said statements; for the purposes of determining the royalties to be paid under this clause the B. F. Sturtevant Company agrees to pay at the rate above mentioned upon the gross sums received for

the economizers comprising the casing, the inlet and outlet 67
gas fittings, the inlet and outlet water fittings and all apparatus within the casing including soot blowers or equivalent devices, but excluding fans or other devices for moving air through the casing, and also excluding freight charges and erection costs where paid or borne by the Sturtevant Company; such sums so paid by the Sturtevant Company to the Foster Wheeler Corporation are agreed to be consideration for the right and license to manufacture only during the pendency of the appeal herein and are to be the sole and exclusive property of the Foster Wheeler Corporation, even though the decree herein should be reversed.

4. In view of the foregoing and in consideration thereof, 68
the plaintiff agrees to consent to the entry of an order suspending the issuance of an injunction during the pendency of the appeal and until the filing with the clerk of this court of the mandate of the United States Circuit Court of Appeals.

Signed in duplicate this twenty-first day of September, 1928.

WILLIAM McKNIGHT,
Counsel for Plaintiff.

ALFRED H. HILDRETH,
Counsel for Defendants.

THE STURTEVANT COMPANY,
by B. S. Foss, *Treasurer.* 69

[Title omitted.]

PETITION FOR APPEAL.

[Filed October 2, 1928.]

To the Honorable Edwin S. Thomas, *Judge of said District Court:*

The above-named defendants, The Connecticut Light & Power Company and B. F. Sturtevent Company, feeling aggrieved by the decree rendered and entered in the above en-

70 titled cause on the day of September 1928, hereby appeal from said decree to the Circuit Court of Appeals for the Second Circuit for the reasons set forth in the assignment of errors filed herewith, and they pray that their appeal be allowed, and that a citation be issued as provided by law, directed to the above-named plaintiff, Power Specialty Company, commanding it to appear before the said United States Circuit Court of Appeals to do and receive what may appertain to justice to be done in the premises, and that a transcript of the proofs, exhibits, evidence and record, and all proceedings in the case and upon which said decree was based, duly authenticated, be sent to the United States Circuit Court
71 of Appeals for the Second Circuit, under the rules of such court in such cases made and provided.

And your petitioners further pray that the proper order as to the security required of such petitioners be made, and so your petitioners will ever pray.

THE CONNECTICUT LIGHT & POWER COMPANY AND B. F. STURTEVANT COMPANY,

by CARMODY & THOMS,
WILLIAM E. THOMS,
their Solicitors.

Appeal allowed October 1, 1928.

72 EDWIN S. THOMAS,
U. S. D. J.

Filed October 2, 1928.

C. E. PICKETT, *Clerk.*

73

[Title omitted.]

ASSIGNMENT OF ERRORS.

[Filed October 2, 1928.]

Now come the defendants in the above-entitled case and file the following assignment of errors upon which they will rely upon their prosecution of the appeal in the above-entitled cause from the decree made by this Honorable Court on the day of September 1928:

1. The District Court erred in holding that Letters Patent of the United States No. 1,565,305, granted to Power Specialty Company on the fifteenth day of December 1925 upon the application of John E. Bell for steam generating plant, was a good and valid patent as to claim 2 thereof. 74

2. The District Court erred in holding that the economizer manufactured and installed by B. F. Sturtevant Company in the plant of and used by The Connecticut Light & Power Company infringed claim 2 of said Letters Patent.

3. The District Court erred in holding that the plaintiff was entitled to an injunction, and in ordering that a perpetual injunction be issued restraining the defendants, and each of them, from directly or indirectly constructing, using or vending to others to be used, any apparatus constructed substantially as claimed in claim 2 of said Letters Patent, and particularly the apparatus manufactured and installed by B. F. Sturtevant Company in the plant of The Connecticut Light & Power Company. 75

4. The District Court erred in holding that the plaintiff was entitled to an accounting, and in ordering that the plaintiff recover the profits which the defendants have received and damages which the plaintiff has sustained, and in referring the cause to a master to take and state the acconnt of profits and assess the damages.

5. The District Court erred in holding that in the patent

76 in suit Bell assembled old elements in a new organization of parts so as to produce a more beneficial result.

6. The District Court erred in holding that Bell made the discovery that by combining extended surface tubes with the closest possible spacing of such tubes, a close rubbing contact of gases on metal, and consequently a high rate of transmission as well as high draft loss, would be produced.

7. The District Court erred in holding that Bell accepted the high draft loss because he appreciated that with his structure there is developed an increase in the rate of heat transmission which more than compensates for the draft loss.

8. The District Court erred in holding that Bell realized
77 that the provision of extended surface tubes alone would not be sufficient and that the compacted heating surface, so arranged and disposed and spaced that it obstructs the draft, results in a highly efficient economizer.

9. The District Court erred in holding that claim 2 calls for an organization and arrangement of the economizer tubes which result in a draft loss,—a beneficial result not obtained prior to Bell's invention.

10. The District Court erred in not holding that claim 2 of the patent in suit was anticipated by the constructions of the prior art because such constructions would necessarily
78 result in a draft loss in operation.

11. The District Court erred in holding there was nothing in the prior art which disclosed the principle of draft loss in the operation of an economizer.

12. The District Court erred in holding that since the specification of the patent, apart from its claims, refers to the several phrases to which defendant takes exception on account of indefiniteness, disclosing many examples of embodiment of the invention, said claim is far from being indefinite when reference is had to the specification.

13. The District Court erred in holding that the terms "ex-

ternal tube surface area" as used in the claim means "external heat absorbing surface", and "per unit of space occupied by said bank" means any unit of volume of the heat absorbing surface of the tubes, and by no means does it mean space occupied by soot blowers or any other apparatus. 79

14. The District Court erred in holding that the differences between the defendant's economizer and that disclosed in the patent in suit are really improvements upon plaintiff's construction and do not avoid infringement.

15. The District Court erred in not holding that claim 2 of said Letters Patent was invalid by reason of anticipation by, and lack of invention over, the prior art as disclosed in the record. 80

16. The District Court erred in not holding that claim 2 of said Letters Patent was invalid because of the vagueness, uncertainty and indefiniteness of such claim and of the specification of said Letters Patent.

17. The District Court erred in awarding costs to the plaintiff.

18. The District Court erred in not dismissing the bill.

Wherefore, the appellants pray that such decree be reversed, and that said District Court for the District of Connecticut be ordered to enter a decree reversing the decision of the lower court in said cause. 81

CARMODY & THOMS,
WILLIAM E. THOMS,
Solicitors for Defendants-Appellants.

[Note by CLERK. On October 1, 1928 the defendants deposited with the clerk two hundred and fifty dollars ($250) in cash in lieu of bond on appeal.]

82 CONDENSED NARRATIVE STATEMENT OF EVIDENCE.

Plaintiff's Prima Facie Proofs.

Plaintiff's counsel offers in evidence Bell patent No. 1,565,-305, granted December 15, 1925 to Power Specialty Company, as "Plaintiff's Exhibit No. 1".

It is stipulated and agreed for the purposes of this case between the parties hereto:

First, that the parties to this suit are incorporated as alleged in the bill of complaint.

Second, that Power Specialty Company, the plaintiff herein, is now and has been since December 15, 1925 the owner
83 of the Bell patent No. 1,565,305, in suit.

Third, that the Connecticut Light & Power Company, the defendant herein, since the issuance of the Bell patent No. 1,565,305, and prior and subsequent to the commencement of this suit, at Devon, Connecticut, within the district of Connecticut, used and operated a steam generating plant correctly illustrated in the drawings which will be later offered in evidence and marked as follows:

Plaintiff's Exhibit 2: Fig. 1, elevation partly in section of furnace, boiler and economizer.

Fig. 2, vertical section of economizer and casing on enlarged scale.

84 Fig. 3, vertical section of economizer tubes and headers upon still larger scale.

Plaintiff's Exhibit 2-B, perspective view of economizer section.

Plaintiff's Exhibit 2-C, vertical longitudinal section.

Plaintiff's Exhibit 2-D, horizontal section of tubes and headers.

That the said plant comprises a furnace section F, a boiler section B, and an economizer section E.

That the elements of the economizer consist of water 85
tubes 1 and discs 2, and are arranged to have dimensions as follows:

(a) The water tubes 1 have an internal diameter 1.875 inches.

(b) The external diameter of the tubes 1 is 2.25 inches.

(c) The outside diameter of the discs 2 is 4.75 inches.

(d) The discs are placed upon the tubes 1, 1 inch apart from center to center.

(e) The discs 2 are in thickness 1.25 inches.

(f) The external heat absorbing surface of the tubes 1 per lineal foot length is 2.954 square feet.

(g) The distance between the centers of tubes 1 in the 86
same horizontal row is 5.5 inches. The distance between the centers of tubes in adjacent rows is 7 inches.

(h) The water tubes 1 are 16 feet in length between headers.

It is also agreed between the parties that printed and photostatic copies of the United States and Foreign Letters Patent from the United States Patent Office may be introduced in evidence with the same force and effect as the originals, or duly authenticated and certified copies, and that the date of filing appearing thereon shall be accepted prima facie as the true filing dates by all, subject to correction by the production of originals or duly certified copies thereof. 87

Plaintiff's counsel offers in evidence the several drawings referred to in the stipulation as "Plaintiff's Exhibits No. 2", "No. 2-B", "No. 2-C" and "No. 2-D".

Plaintiff's counsel offers in evidence copy of letter from Power Specialty Company to The Connecticut Light & Power Company, Waterbury, Connecticut, dated January 27, 1926, which constitutes notice of infringement of the patent in suit, as "Plaintiff's Exhibit No. 3".

It is stipulated that the plaintiff, Power Specialty

88 Company, has changed its name to Foster-Wheeler Corporation.

SIDNEY A. REEVE, a witness called on behalf of the plaintiff, having been duly sworn, testified as follows:

Direct Examination by Mr. MCKNIGHT.

My name is Sidney A. Reeve. I reside in New York City and am sixty-one years old. I am a consulting and mechanical engineer and practice my profession in New York City. I have testified before as a patent expert in patent causes and I understand the patent in suit.

The patent in suit relates to a particular form of economizer. An economizer is a device for heating feed water
89 as it approaches the boiler in a steam generating plant. The best insight into the nature of the patent can be derived from Fig. 1. In Fig. 1 is visible, at the bottom, the furnace consisting of two mechanical stokers feeding the coal in from right and left respectively. Above the furnaces in Fig. 1 is the space A^1 constituting the combustion chamber where the gases are completely burned. Immediately above are the tubes of the boiler proper marked B^3. Above the nest of tubes B^3 are the tubes C of the superheater. The gases in leaving the furnace chamber A^1 are guided by baffle plates up toward the left hand, across the nest of tubes into the
90 upper corner of that rectangular space. Then they move horizontally to the right over the superheater pipes C. They are forced downwardly across the tubes by the baffle plate B^8, thence around under the lower edge of that baffle plate and across the nest of tubes a third time up into the flue A^2. That leads the gases up into the nest of tubes above D^1 which constitute the economizer. After traversing those tubes the gases pass to the draft fan G which looks like a snail shell at the top of the bank of the figure whereby they are driven into the stack.

Now, of all of that apparatus we are interested here pri- 91
marily only in the economizer or the topmost of the three sets of tubes. The reason for the existence of an economizer needs a little explanation in steam engineering. Your Honor is doubtless aware of the fact that when water is boiled in a pan as on a cook stove, it boils at a temperature of 212 degrees F. at sea level, but if the pressure be altered on the surface of the water, the temperature of the ebullition varies. If you carry your sauce pan up into the Rocky Mountains, you may get a boiling point of 180 degrees F., and it will take five or six minutes to soft boil eggs at sea level; but if, on the other hand, you bottle up your tea kettle
so that the steam pressure rises, the temperature rises before 92
the ebullition can take place. That means that in ordinary boiler practice the temperature within the boiler is determined solely by the pressure, the pressure being controlled by a safety valve. For instance, in the boiler pressures which were standard when I was a young man, 80 or 100 pounds, the temperature of ebullition is something over 300 degrees F. With modern boiler plants the pressures are much higher, ranging from 250 to 350 or 400 pounds, and the temperature of ebullition gets up above 400 degrees F. That means that every portion of the boiler proper is at that
temperature. The water can be no cooler than 410, say, 93
because it is mixing everywhere with bubbles of steam, and the steam on the other hand can get no higher than 410, because it is everywhere in contact with the water, and as heat is applied, instead of the temperature rising, merely some of the water turns into steam.

The bearing of that upon the economizer of the plant is this, that the gases going to the flue cannot be cooled by the boiler lower than to within a reasonable distance above the boiler temperature; that is to say, if your boiler temperature is low, at 300 degrees, as it used to be many years ago, then

94 you can cool your gases down to 400 or 500 degrees F. before they pass to the stack, allowing 100 or 200 degrees difference of temperature for the transfer of heat.

If, on the other hand, you carry a higher pressure so that the boiler temperature is much higher, then the furnace gases have to depart to the flue at a correspondingly higher temperature, 100 or more degrees higher, because the boiler temperature is 100 degrees higher. The result of that has been the gradual introduction of the use of what are called "economizers". Economizers are merely a device equipped with heating surfaces subjected to the furnace gases, just as the boiler is, but separated from the boiler and receiving the
95 feed water first.

In the present case, referring to Fig. 1 of the patent in suit the feed water enters at the pipe marked "I", at the upper right-hand corner of the diagram, and proceeds successively down through the various tubes until it reaches the pipe J whence it proceeds to the boiler proper. This separation of this upper heating surface from the boiler proper permits the water entering the economizer to retain its natural temperature, instead of being heated immediately to boiling temperature by condensing some of the steam in the boiler. Instead of being heated in that way, it can take up some more of this heat from the flue gases, and if the water enters at a
96 temperature say of 200 degrees, whereas the boiler temperature is 400 degrees or over, obviously the flue gases can be cooled off by a profitable abstraction of their heat by some 200 degrees more than would be the case if the economizer were not present.

That is the essence of an economizer. It has a heating surface exposed to the departing gases which naturally maintains itself at a temperature lower than the boiler, because it is separated from the boiler.

In this economizer the cold water comes in at the top and

flows downwardly toward the boiler. That is what is called 97
counter-flow; that is, the coldest water is in contact with the coolest gases just as they depart from the stack, and as the water becomes heated towards boiler temperature by traversing the economizer, it finds itself in contact with higher and higher temperature of flue gases, the closer it gets to the fire.

Returning now to the face of the patent, the only other figures to which I need refer at present are Figs. 2, 6 and 7. They show some of the details of the economizer pipes and connections. Fig. 2 shows the economizer across in the other direction from Fig. 1. But I thought for the moment that we need not trouble ourselves with those intermediate
figures. The upper part of Fig. 2 shows the economizer 98
tubes as equipped with what are commonly known as gills. Those are shown in larger sections in Fig. 6. They are the annular protuberances on the outside of the pipe. They are sometimes called fins, sometimes gills. The stipulation has referred to them as discs. Fig. 6 shows an inner tube *d* which is of steel.

The function of these discs is to increase the heating surface exposed to the hot gases in proportion to the inner heating surface of the metal which is in contact with the water. It is common knowledge that for a given difference in temperature the rate of heat transfer between metal and
a liquid is much greater than the rate between a metal and 99
a dry gas. Water or steam will take up or impart heat to the metal very much more rapidly than air or any dry gas. Therefore, it is proper in these economizer tubes to increase the outer surface of the tube in proportion to the inner surface. Referring now to the text of the patent, that text is long in the sense of referring to a number of matters which are not pertinent to this present issue, which concerns only claim 2. It will therefore save the time of the court, I believe, if I select some portions from the text of the patent for

100 quotation and special emphasis. Beginning on page 1, with line 9, the text reads:

> "The general object of my invention is to provide improvements in method of, and apparatus for generating steam. More specifically the object of my invention is to provide for the more effective utilization of an economizer for transferring heat to boiler feed water from the partially cooled products of combustion leaving the boiler furnace.
>
> It has long been common practice to preheat boiler feed water by the use of an economizer, but heretofore the economizer has ordinarily been regarded as an ad-
> 101 junct of the boiler, which, while of value, is distinctly of secondary importance as compared with the boiler proper. I have discovered, however, that highly beneficial results, both with respect to the thermal efficiency and operative economy of a steam generating plant, and with respect to the initial construction and maintenance costs, may be obtained by making the economizer a more important element of the steam generating plant than has heretofore been the case."

That is to say, your Honor, the patent concerns an improvement in a device which has long existed. Continuing
102 the quotation:

> "To this end I substantially increase the ratio of economizer heating surface to boiler heating surface over that heretofore employed in commercial practice, and provide the economizer heating surface in an economizer of special construction characterized by its compactness and requiring a draft much stronger than is required in the types of economizers heretofore in use to move the heating gases through it. In the preferred practical mode of carrying out my invention I employ

economizer tubes similar in construction to those hereto- 103
fore employed in the well known Foster superheater, in that each tube comprises an inner tube of wrought steel which is surrounded by an externally corrugated tubular cast iron casing. In the economizer which I employ, the special tubes are preferably spaced close enough together to give an aggregate external tube surface area per unit of volume of space occupied which is several times greater than is obtained or is practically possible of attainment in economizers of the types heretofore in commercial use. The compactness of the economizer which I employ not only reduces the bulk and initial
cost of the economizer, but makes it practically feasible 104
to enclose the economizer in a housing which forms part of the boiler setting and is sufficiently air tight to practically eliminate air leakage into the economizer, notwithstanding the high draft suction impressed on the economizer.

The special economizer tube construction employed provides a very large amount of external heating surface swept by the heating gases, in comparison with the internal wet surface of the tube; is well adapted for high pressure work since the steel inner tube may readily be of sufficient strength to resist an internal pressure
as high or higher than the boiler steam pressure, and 105
the cast iron casing section protects the steel inner tube from the corrosive effect of the furnace gases which rapidly destroy steel economizer tubes directly exposed to the action of the heating gases, especially in the low temperature portion of an economizer."

From that point, line 83, page 1, to line 13, page 2, I think is irrelevant to the topic in hand. The matter following, line 13, page 2, is pertinent but is rather technical. I need not

106 quote it into the record, because in the form in which it stands it would hardly be of use to your Honor. I would point out, however, that the essence of the remainder of that column may be stated in the following words which are quoted from the text beginning with line 38, but not including all of the words in the text. Selecting in that manner, I quote as follows:

> "It follows therefore, that in a boiler . . . which absorbs heat from furnace gases, that the bulk of the heat so absorbed is absorbed in such a manner as to make the velocity of the gases over the surface relatively unimportant. The same condition does not however exist
> 107 in connection with the absorption of the heat given out in the lower gas temperatures, where the velocity is the controlling factor. I, therefore, propose arranging my boiler surface . . . without regard to gas velocity."

I am condensing to simplify.

> "I, therefore, propose arranging my boiler surface . . . without regard to gas velocity, and arrange the economizer surface . . . to obtain the maximum allowable velocity compatible with the draft conditions."

I omit from there to line 63, and then begin again.

108

> "The tubes should be horizontally disposed to restrict the tendency of furnace dust to deposit on the sides of the corrugation ribs and to facilitate cleaning the tubes. Furthermore, the tubes should extend transversely to the direction of flow of the heating gases and should be arranged in rows substantially transverse to the direction of flow of the heating gases, with the tubes in adjacent rows staggered; and the tubes should be closely spaced so that the average distance between tube centers is small, for example in the neighborhood of one

and one-quarter times the maximum tube diameter, and 109
the area of the gas path between a pair of adjacent tubes in adjacent rows transverse to the direction of the gas flow should not be less than one-half the area of the gas path between adjacent tubes in the same row, to insure proper contact between the heating gases and the tubes, and to minimize the frictional resistance to the flow of the heating gases through the economizer and thereby minimize the draft required to remove the heating gases through the bank of the economizer tubes."

The word "staggered" which appears in the last quotation refers to the disposition of the tubes as they may be 110
seen in Fig. 7. That is to say the tubes are arranged in oblique rows slantingly across each other so that the gases passing up between any pair of tubes find themselves in contact with a single tube just beyond. Continuing with the text of the patent, page 2, line 89:

"Where, as will ordinarily be the case, the high draft suction required for operating a steam generating plant in accordance with the present invention cannot be provided by stack or natural draft but requires an exhaust fan, I have found it advantageous to make provisions for sending a portion only of the furnace gases leaving the boiler proper through the economizer when the 111
steam generating plant is operating under peak load conditions."

The inventor there starts to talk about a device, namely, the by-pass, which does not enter into our present topic. In the beginning of that quotation he expresses his sense of the need for a high draft suction, and corroborates the matter already quoted from the earlier portion of page 2. The remaining matter on page 2 refers to the counter flow of the

112 water through the economizer against the path of the gases, which topic also does not concern us here.

By "counter-flow", I mean that the water flows downward from the top of the economizer to the bottom, whereas the gases flow upward against that flow of water.

Turning to page 3, the matter from line 6 to 49, inclusive, refers to matters of corrosion which probably will not be of importance here, at least not immediately. Beginning with line 50 on page 3, the inventor proceeds to a more specific description of his invention leading up to the drawings:

> "My invention comprises methods of and apparatus for effectively utilizing the above mentioned discoveries
> 113 and principles of operation. The various features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, however, its advantages and specific objects obtained with it, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described preferred embodiments of my invention."

He then proceeds to refer to the drawings in detail, in which we have no reason at present to follow him. Begin-
114 ning with line 101 on page 3 we have the description of the drawings, which refers specially to the economizer and which should be quoted here:

> "Mounted above the boiler furnace proper is the economizer D which, in the construction illustrated, comprises two vertically elongated banks of horizontally disposed economizer tubes D^1. The tubes D^1 are enclosed in a housing which, in the preferred construction illustrated, comprises an inner metallic shell D^2 and an outer metallic shell D^3 with a space D^4 between the two shells

which is filled with a suitable material such as powdered 115
Sil-o-cel which serves both as a heat insulating material, and also as a packing preventing leakage through the joints in the shells D^2 and D^3. The tubes D^1 each comprise an inner tube *d* of wrought steel and an externally corrugated tubular casing d^1 formed of cast iron sections which fit snugly on, and may be shrunk in place on the tubes *d*. In the simple and effective construction illustrated, the tubes D^1 are supported in the end walls of the shell D^2 and in an apertured tube sheet D^5 placed midway between the end walls. One of the end walls is formed with apertures D^6 a trifle larger than the maximum diameter of the tubes D^1, so that the latter may 116
be axially removed from, and replaced in the housing through these apertures when conditions make this desirable."

The remainder of the page is a detailed description of construction which I think it is not necessary to quote at present. The same applies to the first portion of page 5. The first paragraph describes the action of the fan which is plain enough from Fig. 1. The second paragraph refers to the path of feed flow, which has been sufficiently debated. The third paragraph refers again to corrosion, which is not of primary interest at present. 117

Beginning with line 56, however, I would quote as follows:

"This heat absorbing capacity is of course greatly enhanced by the relatively great amount of external heating surface in contact with the furnace gases which it provides. The area of external gas swept heating surface of each tube may advantageously be in the neighborhood of $5\frac{1}{2}$ to $6\frac{1}{2}$ times as great as in the internal wet surface area of the tube.

"In the construction shown in Figs. 1 and 2, the externally corrugated economizer tubes D^1 are arranged in

118 horizontal rows which extend transversely to the general direction of gas flow past them, and are also arranged in rows extending parallel to the general direction of gas flow, the tubes in the adjacent horizontal or tranverse rows being staggered. The tubes D^1 are closely spaced. In ordinary practice I prefer to make the average of the distances between the centers of each tube D^1 and the centers of the immediately adjacent tubes about one and one-quarter times the maximum tube diameter."

The inventor then refers to a matter which might seem trivial but which really has a bearing upon this question
119 which he has already emphasized, of space occupied.

Proceeding with the text of the patent:

"Notwithstanding the small space between the exterior surfaces of the economizer tubes, the internal tubular parts *d* are sufficiently far apart to permit the ready use of suitable end connections between the different tubes, since these connections are external to the inner metal shell D^2 of the economizer housing and the tube casings d^1 need not project through the shell D. With this spacing the external heat absorbing surface of the economizer per unit of space occupied by the bank of economizer tubes is several times greater
120 than is practically possible with economizer tubes of the same internal diameter and having smooth external walls, especially since with the smooth walled tubes the minimum distance between the tubes is limited by the necessity for providing space for the necessary end connections to the tubes."

The next paragraph refers to the arrangements for washing the soot and ashes off the tubes, and all which follows is irrelevant, I think, down to line 11 of page 6. Beginning there, the text of the patent reads:

"The close spacing of the economizer tubes, and their 121
corrugated exterior surfaces provide tortuous gas paths through which the heating gases move with relatively high velocity thus insuring a high heat transmission factor and a large economizer capacity per unit of volume. The consequent comparatively small economizer volume required for a given duty makes it practically feasible to employ an economizer housing which is substantially air tight, thus practically eliminating air leakage into the economizer notwithstanding the comparatively high draft suction required to move the heating gases through the boiler and economizer. Air leakage
is objectionable both because of the cooling effect of the 122
air leaking in, and also because of the resultant increase in volume of the gases which must be handled by the draft creating fan. Air leakage tending to increase the exhaust fan capacity required is especially objectionable in the practice of my invention because the relative high draft suction which I ordinarily employ requires a considerable expenditure of fan driving energy at normal load even when there is no leakage at all. It has heretofore been the practice to operate a boiler plant comprising an economizer with a draft suction which ordinarily does not exceed one and three-quarters inches of
water, at a maximum. In proceeding in accordance 123
with the present invention, I may advantageously employ a draft suction at normal load as high as three, four, or five inches of water, and of which much more than half is utilized in moving the heating gases through the economizer."

From that point, all of the text of the patent, I believe, is irrelevant to what we are particularly interested in here, down to the claims of which claim 2 is the only one at issue

124 here. Summarizing, the invention of Bell is for an economizer which is of a more compact form as measured in amount of heat surface per cubic foot of volume than had heretofore been in use, one which required a much higher draft suction in order to overcome its resistance, and one which accomplished these ends by the specific use of horizontal staggered tubes surrounded by discs. That, in ordinary language, constitutes the principal features of his invention as he contrasts them with what was then in practice.

Explaining defendant's apparatus as shown in Plaintiff's Exhibits 2, 2-A to 2-D, inclusive, that apparatus is shown in complete form in Exhibit 2. Fig. 1 of Plaintiff's Exhibit 2
125 is a vertical elevation partly in section corresponding with Fig. 1 of the patent in suit. Beginning at the bottom, F is the furnace space which is fed with fuel by a single mechanical stoker instead of the two shown in the patent. Above the furnace F is the boiler proper B, consisting of two banks of tubes separated by a space in which I infer the superheater is to be located, but is not shown in the drawing because the superheater is not a matter pertinent to the issue at hand.

As in Fig. 1 in the patent in suit, the gases are deflected by baffle plates upwardly and to the left, are then led hori-
126 zontally around and downwardly to the right, and thence upwardly again, making a third pass across the upper bank of boiler tubes to the flue leading to the economizer E.

The economizer E consists of horizontal tubes arranged in a staggered fashion and divided here into five sets of four headers each. At the top of the economizer the gases pass to the left downwardly to the fan which carries no symbol in the drawing, whence they are driven upwardly into the stack at the upper left hand.

In Plaintiff's Exhibit 2 the figure 2 at the lower right hand shows the economizer on a somewhat enlarged scale, show-

ing more distinctly the economizer tubes surrounded by 127
discs.

Fig. 3 of Plaintiff's Exhibit 2 shows the economizer tubes in still larger detail in horizontal section. Only three tubes out of the set are shown, the tubes proper being numbered 1 and the discs or gills again by 2. The ends of the tubes are expanded into cast iron or cast steel headers which are connected by elbow connections so as to direct the water in a continuous path through the economizer.

Referring to Plaintiff's Exhibit 2-A, a perspective view of defendant's economizer, we get a clear idea of the general arrangement of the tubes, the water connections for the inlet or feed water under a pressure above boiler pressure 128
are shown by the upper left hand leading into two different headers at once. The water then passes across the first two layers of tubes, that is, in 18 tubes in multiple, across to the right hand headers, thence is led downwardly by vertical elbow connections to the next pair of headers which it traverses to the left, thence is led downwardly by outside connections to the third pair of headers, and so back and forth across the economizer until it finally leaves at the bottom where the dotted arrows show, in its most highly heated condition.

Plaintiff's Exhibit 2-B shows in perspective the arrangement of a single pair of headers with the connecting econo- 129
mizer tubes partly clear of discs and partly covered with discs.

Plaintiff's Exhibit 2-C shows again in vertical section the tubes with their discs and the headers into which they are expanded with the elbow connections running from header to header.

Plaintiff's Exhibit 2-D, Fig. 7, shows a horizontal section of a pair of the headers with the tubes expanded in and with curved arrows showing the path of the water through the

130 section from the inlet at the upper left through nine tubes in parallel to the outlet at the right.

According to the stipulation, these heater tubes have an internal diameter of $1\frac{7}{8}$ and an external diameter of $2\frac{1}{4}$ inches. The discs have an outside diameter of $4\frac{3}{4}$ inches, and are placed on the tubes, 1 inch apart from center to center. The discs are one-eighth of an inch thick. The external heat absorbing surface amounts to 2.94 square feet per linear foot of pipe.

The distance between the centers of tubes in the same horizontal row is shown in Fig. 7 of Plaintiff's Exhibit 2-D as $5\frac{1}{2}$ inches. The distance between the center of tubes in
131 adjacent rows, as shown in Plaintiff's Exhibit 2-C, Fig. 6, is 7 inches. The tubes from header to header, as shown in either Fig. 6 or Fig. 7, is 16 feet.

[NOTE: At this point Prof. Reeve temporarily left the witness stand in order that certain facts might be established so that he could continue with his comparison between defendant's device and the structure of the patent in suit.]

WALTER F. KEENAN, Jr., a witness called on behalf of the plaintiff, was duly sworn and testified as follows:

Direct Examination by Mr. McKNIGHT.

132 My name is Walter F. Keenan, Jr. and I live at Pelham Manor, New York. I am 42 years of age and am chief engineer of Foster-Wheeler Corporation, having held this position since 1921, prior to which time and since 1911 I was connected with the Power Specialty Company.

I have examined the bare surface tube economizer installed in the plant of the Metropolitan Power Company at Middletown, Pennsylvania, in 1924, and I know the construction of these economizers. I have had a drawing made representing these, which I now identify. This drawing shows two vertical views of a plain tube economizer installed at the Metro-

politan Power Plant at Middletown, Pennsylvania, by B. F. Sturtevant Company of Hyde Park, Mass. This economizer at the Metropolitan Power Company plant is of a construction similar to that shown in Fig. 2, page 4, of the catalogue entitled "Sturtevant lead coated extended surface type Y economizer". 133

It is stipulated that the catalogue referred to by the witness was printed and distributed by B. F. Sturtevant Company of Hyde Park, Boston, Mass.

[Plaintiff's counsel offers this catalogue in evidence as "Plaintiff's Exhibit No. 4".]

The internal diameter of the tubes of this economizer was about 2 inches, and the external diameter 2½ inches. The centers of the tubes in the same horizontal row were 5 inches apart, and in the vertical rows were 4½ inches. The tubes were 11 feet, 11 inches long between headers. There are three banks of tubes and the total height of the three banks is 20 feet, 3 inches. The banks are spaced 25 inches apart. The distance from the center of the lower tube in one bank to the center of the upper tube in the next bank below is 29½ inches. The spacing of the tubes in each bank is 4½ inches and the 25 inch dimension just given is arrived at on the assumption that the lower row of one bank and the upper row in the other bank each occupy a space of 4½ inches high. 134 135

From the above dimensions the external tube surface area of the tubes is 4.19 square feet per cubic foot of space occupied.

[Plaintiff's counsel offers in evidence the drawing identified by the witness and marked "Keenan Drawing of Metropolitan Power Co., Middletown, Pennsylvania, Sturtevant Economizer", as "Plaintiff's Exhibit No. 5".]

I have also examined the bare tube economizer installations in the plant of the Edison Electric Illuminating Company of

136 Boston, Massachusetts, and I know their construction. I have made a drawing which correctly illustrates these economizers, which drawing I now identify. These economizers were installed by Babcock & Wilcox Company in 1924.

The internal diameter of the tubes is about 1.65 inches and the external diameter 2 inches. The distance between centers in the same horizontal row is $3\frac{1}{2}$ inches and in the vertical rows the average distance is 5 inches. The spacings at the header ends are alternately 3 inches and 7 inches, averaging 5 inches. The length of the tube between headers is 23 feet, 9 inches, and the height of the bank of the tube is 16 feet, 8 inches. From the above dimensions the external
137 tube surface area of the tubes is 4.22 square feet per cubic foot of space occupied.

[Plaintiff's counsel offers in evidence the drawing identified by the witness and marked "Keenan Drawing Edison Electric Illuminating Co. of Boston, Mass., Babcock & Wilcox Economizers", as "Plaintiff's Exhibit No. 6".]

I am the W. F. Keenan who swore to an affidavit used in the prosecution of the Bell patent in suit in the United States Patent Office.

[NOTE: At this point Mr. Keenan left the witness stand and Professor Reeve returned and continued his testi-
138 mony.]

Direct Examination of Professor REEVE *continued by* Mr. MCKNIGHT.

Comparing the defendant's apparatus with the disclosure of the Bell patent in suit, and particularly with respect to claim 2, and beginning with the first element of the claims:

"The combination with a boiler and its furnace, of an economizer comprising a bank of horizontally disposed tubes externally swept by the heating gases leaving the furnace—"

That we found both in Fig. 1 of the patent and in Plaintiff's 139
Exhibit 2, Fig. 1, showing defendant's devices. In fact, the general arrangement of the economizer with its tubes in positional reference to the boiler and the furnace below is almost identically the same in defendant's device as in the patent in suit. Continuing with claim 2, the next item mentioned is:

> "—said tubes being each provided with external circumferentially extending ribs proportioned and disposed to make the external surface area of the tube several times greater than its internal surface area."

That proportion in defendant's device amounts to 5.8, as 140
the proportion of the external heating surface to the internal heating surface for any given length of tube. The next item mentioned in the claim, referring to the tubes, says:

> "each of a length many times greater than its *maximum* diameter",

—that is so obvious from the drawings and from the proportions of about two inches in diameter to about 16 feet in length, that it hardly needs mention in mathematical form. Continuing, the claim says:

> "and being spaced to provide an external tube surface area per unit of space occupied by said bank which is 141
> several times greater than is practically possible with tubes which are of the same internal diameter and have smooth outer walls."

Drawing a comparison now between the smooth tube economizers which were mentioned by Keenan, and are shown in Plaintiff's Exhibits 5 and 6, and the tubes with discs in defendant's plant, I find the following proportions by computation:

The Sturtevant plain tube economizer at Middletown, Pennsylvania, figures 4.18 square feet per cubic foot. The Bab-

142 cock & Wilcox plain tube economizer at Boston figures 4.21 square feet per cubic foot. The Sturtevant economizer at Devon, Connecticut, carrying discs or gills, 10.47 square feet per cubic foot, or more than twice either of the other samples of plain tube economizers.

From this basis I find that the language of the claim:

> "Spaced to provide an external tube surface area per unit of space occupied by said bank which is several times greater than is practically possible with tubes which are of the same internal diameter and have smooth outer walls—"

143 appears in defendant's structure.

Cross Examination by Mr. HILDRETH.

In making this computation which gave the figure of 10.47 square feet of external heating surface per cubic foot of space occupied in defendant's economizer at Devon, I computed merely the external surface of the tubes, which is a matter of simple geometry, and took the cubic capacity occupied as that between the headers, including the small waste space which is left at right or left hand of each row of tubes by the staggering.

I have not the details of my computation here. I do not remember what those over-all dimensions came to. They
144 were computed as the space occupied by the bank, including the waste space at the end of either row.

With the staggering on the rows of nine tubes sets, the end tube of each alternate row stands out by half a tube diameter from the one below or above, so that at left and right alternately there is a space corresponding to one-half of a tube. I might explain that I did not measure merely from the outside of the left-handmost tube to the outside of the right-handmost tube. I allowed beyond that the same space which the designer has allowed for each tube within the bank

of tubes. I allowed outside of each gill circumference or disc 145
circumference the same space that is allotted to that periphery on its inner side toward the other nest of tubes. For a vertical height I allowed below the lowermost disc and above the uppermost disc that same allowance of space as appears within the bank. In other words, I took the capacity of the bank as a unit, the four headers, the four elements forming one section.

The stipulation states the space between those tubes is 5½ inches horizontally and 7 inches vertically. I therefore went 3½ inches above the topmost tube centers and 3½ inches below the bottommost tube centers for the boundaries of the space
which might legitimately be said to be occupied by the bank. 146
Similarly, speaking of horizontal dimensions, I went to the left of the left-endmost tube center 2¾ inches and to the right of the right-handmost tube center 2¾ inches for the lateral bounding planes of the space which might legitimately be said to be occupied by the bank. That gave me a cubic volume which would be independent of the dimensions of the bank, except as those are affected by the fact that the economizer is only nine tubes wide. Of course as you increase the width of the economizer these waste spaces at right and left would become smaller in proportion, but with the exception of that one feature the volume which I assumed
applied merely to a bank of indefinite extent. I did not take 147
into consideration the four spaces between those five portions of the economizer.

The boiler as shown in the Bell patent in suit at B, the superheater as shown at C, and the economizer as shown at D are all what are generally known as heat transfer apparatus. Their purpose is to take the heat generated by the burning of the fuel and transform it into useful energy. The boiler is where the first application of heat in the fire is made. The waste gases from the boiler are then applied to

148 the superheater and more heat is taken out of the gases. Finally the gases come to the economizers, which is the last apparatus in the line, and that abstracts still more heat from the gases. It is not exactly correct to say that the superheater and the economizer are both pieces of apparatus for utilizing waste heat from the boiler gases, because after the gases traverse the superheater they again traverse the tubes of the boiler proper, but to a certain extent they take out their share of the heat from the gases generated by the burning of the fuel.

The flow of water in the Bell economizer is downward and the gas upward and this is counter-flow. Counter-flow does
149 not always mean the gas is up and the water is down, but merely that they move in opposite directions. As to whether it has been well known, or been a common practice in the economizer construction, to move the water in one direction and the gas in the opposite direction, I do not know whether we could state that or not. There have been certain attempts made in that line. Just at the moment I am not prepared to answer that question exactly. Bell was the first to inaugurate the counter-flow principle in an economizer under certain specified conditions. The patent refers to that matter on page 2, beginning with line 112 and ending at line 5 on page 3. The inventor refers to that same topic on page 5, from
150 lines 18 to 24, inclusive.

Referring to my summarizing of the invention of the Bell patent where reference was made to much higher draft resistance than had heretofore been used, and to the staggered arrangement of the tubes of the economizer, there is no specific reference in claim 2 to draft resistance or to the staggered arrangement.

There is nothing new with Bell in the arrangement of the boiler and the baffles. That is old practice and the superheater is old.

With regard to the flow of water in defendant's economizer, 151
this is set forth very plainly in Fig. 4 of Plaintiff's Exhibit 2-A. The water enters at the upper left-hand corner of the stack of tubes and divides thence in a dual path, one going directly into the left-hand end of the first header, and the other going into the right-hand end of the second header. Thence it flows to the right, dividing itself into 18 paths, through the first two elements of tubes and descends at the right in the elbow connections to the lower pair of headers of that section and goes back to the left again through another set of 18 tubes. It does this five times in succession, each within one section of the economizer, and finally departs at the bottom in a dual path which joins into a single feed line 152
to the boiler just outside the economizer. There is no connection between these dual paths from the top to the bottom of the economizer. They are entirely separate and distinct.

Bell was not the first to produce the horizontally disposed tubes in an economizer, but I have never seen an economizer but Bell which had horizontal tubes. So far as I am informed, Bell was the first to arrange economizer tubes in rows substantially transverse to the direction of flow of the heating gases. So far as my acquaintance with actual economizers goes, the staggering of the horizontal tubes, that is, with the tubes in adjacent rows staggered, was a feature of novelty with Bell. Vertical staggered tube economizers were com- 153
mon. The use of an exhaust fan was not new with Bell.

The flanges marked "D'" in Fig. 6 of the Bell patent are described as of cast iron and shrunken on to the tubes.

With regard to the reference in claim 2 of the patent in suit to the tubes as "being each of a length many times greater than its maximum diameter" and particularly to the word "many", I cannot add to its meaning. I have not measured the drawing of the Bell patent to see or interpret an exact ratio. I do not know in a mathematical sense what

154 "many" means in effect. There is not in the context any specific mention of any specific ratio. The only drawing which could give you even an approximate ratio for that is Fig. 6, and there we find ourselves at fault, because the tube is shown with two portions broken out. The portion which remains, however, is sufficient to show a ratio of over 30 to 1 between length and diameter. As to whether I find the word "many" used in the specification in connection with the length of these tubes, I do not remember any specific reference to it.

As to the reason for making the tubes in length many times their diameter the patent tells us this reason in the
155 sense that he tells there to get his contact with the surface as close as possible. It is obvious that with a short tube you cannot get your surface in proportion the same as with a long tube. As you shorten the tube the ratio runs down and the flue area passage is restricted in proportion to the heating surface involved. Of course you could figure any one cubic foot inside your casing and you would get the same result with a short tube as with a long one, but when it came to practical application you could not possibly get your compactness with a short tube.

In figuring the area in square feet surface per cubic foot of space, I disregarded entirely the length of the tubes, as that
156 is immaterial in the interpretation of the drawings and of claim 2. It is not immaterial in my opinion whether the tubes be long or short so far as compactness or the area per cubic foot is concerned, because the inventor has plainly shown a long tube in his drawings, and with ordinary engineering knowledge we know that a long tube has to be provided. It is true that the language of the claim does not demand that you bring in the length of tube into any computation. The language of the claim being in those words

"practically possible" which force you to go to considera- 157
tion of practical conditions when they enter the question.

I have not determined the ratio of square foot of heating surface per unit of cubic capacity in the structure of the Bell patent, for there is no way of doing that so far as I know. The term "bank" as applied to the defendant's construction means economizer sections exclusive of the headers. I should say the defendant's economizer comprises a bank divided into five sections. The word "bank" might apply to the whole exclusive of the sections, but it might apply to any one section.

In my computations with regard to defendant's econo- 158
mizer I have in general excluded the spaces intervening between the five sections, but I did not measure such intervening space as involving all that from metal to metal. Each tube was assumed to be surrounded by the same space at the top and bottom of each section, as was true of the interior section.

It is usually most convenient to have the gases flow upwardly rather than downwardly through an economizer, but there are many cases where the gases flow downwardly through an economizer.

Redirect Examination by Mr. McKnight.

Referring to the last clause of claim 2 of the patent which 159
specifies the tubes as spaced to provide an external tube surface area per unit of space occupied by the bank and in fixing upon a method of computation I had in mind what Bell says in his specification on page 5, line 88, and also page 1 beginning at line 50 and the disposition of the tubes as shown in Fig. 1 and Fig. 2 with this difference. In Fig. 1 the casing of the economizer is shown corrugated so that they are not left, those waste spaces at the ends of the tube rows which I mentioned as included in my computation. In other words, I was one step more conservative than I might

160 have been in stating the compactness of the Bell economizer, or rather in stating the compactness of the defendant's economizer in terms of the Bell patent. I gave the defendant the benefit of the doubt in taking into consideration these so-called waste spaces because of the staggering.

There is no showing in the drawing of the Bell patent in suit of any horizontal space between the sections of the tubes. In the defendant's construction, as shown in Fig. 3 of the Plaintiff's Exhibit No. 2, these spaces are not occupied by tubes, the surface of which absorbs heat from the upwardly flowing gases, but are left for soot blowers.

161 [NOTE. The examination of Professor Reeve having been completed, Mr. Keenan returned to the witness stand.]

Cross Examination by Mr. HILDRETH.

I personally made the measurements from which the drawings Plaintiff's Exhibits No. 5 and No. 6 were made. With regard to the direction of water flow in the economizer of Exhibit No. 5, the water enters at the bottom and is connected into vertical headers at the right-hand end of the lower bank. There are fourteen of these vertical headers into each of which there are eighteen tubes connected so that the water flows in parallel through all of the tubes in
162 that bank across to the left-hand end, where there are similar vertical headers, and those vertical headers are connected by means of U-bends at the left between the bottom and next to the bottom banks to the next upper bank across which it flows, and then on up through the top bank. The gas enters at the top and flows down through the economizer.

There is a tendency in any up flow of water for the steam to rise with the water to the top of the economizer, and not be pocketed in it. In an economizer where the water velocity is not above some critical point, it is extremely important that the flow of the water be up, but in an economizer where

the water velocity is above a critical point, it is not important. 163

With regard to the direction of gas flow and of water flow in the economizer of Plaintiff's Exhibit No. 6, the water in this economizer enters the header shown at the lower left on the left-hand view. It flows to the right in parallel through all of the tubes in the bottom row into a header, the lower header at the right-hand view, and out of the upper row of tubes. From that header it flows again across, and so on, back and forth up through the economizer. The gas rises through a flue at the side of the economizer, enters the tubes at the top, and flows down.

In the economizers shown in this Exhibit No. 6 there are 164
two rows or two sets of tubes in each header except in the top and bottom headers at the left-hand side. I have drawn in in pencil outlines the headers in the right-hand sectional view, being the section of Exhibit No. 6, and for the upper bank of Exhibit No. 5.

In figuring the areas for the economizer of Exhibit No. 6 I assumed that this economizer consisted of forty rows of tubes, that is the number of tubes high. The vertical spacing is alternately 7 and 3 inches, the average spacing at the center of the economizer being 5 inches. I assumed that each one of the forty rows of tubes occupies a space 5 inches
high. The economizer is 22 tubes wide, and the horizontal 165
spacing of those tubes is 3½ inches. The alternate rows of tubes are staggered, and to allow for the stagger I assumed that each horizontal row occupies a space 22½ times 3½ inches wide, each row being 22 tubes wide and the extra half space being figured to compensate for the stagger. The transverse area occupied by each tube was one-twenty-second of that area. The number of tubes that could be put into a square foot of area would be the area occupied by each tube divided into 144 square inches, or one square foot.

166 That gave me the number of elements or tubes in one square foot of transverse cross-sectional area. Multiplying that by the square foot per lineal foot of tube, I obtained the surface per cubic foot of volume occupied.

I allowed for a little distance on each side of the outside tubes. I allowed for one-half a tube on each side. The tubes are 22 wide, and I took 22 times $3\frac{1}{2}$ inches, plus one-half of $3\frac{1}{2}$ inches. Without the half space added to allow for the stagger, I have as a base a space 22 times $3\frac{1}{2}$ inches wide as the space occupied by 22 tubes, the boundary of which space is beyond the edge of the tube. I have a half
167 a space on the outside of each outside tube in that way. Then I have added to that a half of another space to allow for the staggering.

In figuring this area per cubic foot of capacity in the economizer of Plaintiff's Exhibit No. 5, I did not include the spacings, of which there are two, in the entire height of the economizer.

I have been with the Power Specialty Company since 1911 and am entirely familiar with the economizer manufactured and put out by that company and commonly known to the trade as the Foster economizer. The present standard spacing of the tubes in these Foster economizers manufactured
168 and put out by the plaintiff is $5\frac{1}{2}$ inches horizontally and $5\frac{3}{8}$ inches vertically. The tubes are staggered.

Other spacing have been employed. I have a list of spacings of some older installations. I have here one economizer where the spacing was 6 inches horizontally and $6\frac{3}{4}$ inches vertically. There is another where it was $5\frac{1}{4}$ inches each way. Another, $5\frac{1}{4}$ inches horizontally, $4\frac{3}{4}$ inches vertically. I have another where it was 6 inches each way. There is another where it was $6\frac{3}{4}$ inches horizontally, 6 inches vertically. Then in another style of economizer I have a spacing $7\frac{3}{8}$ inches horizontally and 6 inches vertically.

This is a special design that is used in connection with cement plant work; with a particular type of boiler where it is fitted into the boiler setting rather than outside of it. It is an economizer. 169

As to the length of tubes used by the Power Specialty Company in these Foster economizers, I would not be able to recall exactly the minimum length. Ordinarily the length is from 12 to 22 feet, something like that. I cannot give the length of the tube with the several spacings I have mentioned. I should guess the shortest tube used with the Foster economizer was about 10 feet, but have not looked this up and cannot be certain. The economizer shown on page 24 of the catalogue entitled "The Foster Economizer" published and put out to the trade by the Power Specialty Company (Defendant's Exhibit A), is not an actual installation; it is simply a study, a tenative design. 170

[NOTE. Counsel for plaintiff states that the shortest length of tubes which have been used in the Foster economizer is 7 feet 6 inches.]

The standard tube diameter is 2 inches outside and about 1.7 inches inside, depending a little upon the exact gauge of the tube. The standard outside disc diameter was $4\frac{5}{8}$ inches. That is the size we are now using. We have used different sizes in a few jobs in the past; in fact we tried on a few installations $3\frac{1}{2}$ inches. We have put out 15 economizers with 8 foot tubes. 171

The sleeves or fins are of cast iron, with about 12 discs to the casting, and are heated and shrunk on the tube. That is the way we are now doing. In fact we have expanded the tube into the casting. We have tried on an experimental basis only casting the fins or gills on the tubes but have never done that on a commercial scale.

As to the practice of the Power Specialty Company with regard to the relative size of boiler and economizer, that com-

172 pany has put out economizers in which the heating surface is over 100 percent of the boiler heating surface. That ratio varies from job to job. There are also economizers where the ratio is smaller. The general practice is changing pretty rapidly. At the present time I would say that the general practice was to have a ratio of economizer to boiler heating surface in power plants of from 50 to 100 or slightly over 100 percent, depending on the design conditions in that plant; also depending to a large extent on whether or not economizers are installed in combination with air heaters which will affect in any particular job the amount of economizer surface which it is considered advisable to use.

173 I think it is necessary to make some sort of distinction between boilers in central power station plants and in industrial plants, because in the former the boilers are operated at very high ratings in addition to being somewhat different.

There are many industrial plants where the ratio of economizer to boiler heating surface is somewhat less, although in general I would say that the tendency in industrial plants is to install economizers containing from 50 percent to 70 percent of the boiler heating surface.

An installation where the ratio of economizer surface to boiler surface is greater than 100 percent is United Electric Light & Power Company, Hell Gate Station. I do not know
174 whether that is listed in this paragraph or not. I apparently can find no record or picture in the catalogue of any such installation where the economizer heating surface is as high as 100 percent. I have one here where the ratio was 86 percent. I do not recall any installation of that type but I was under the impression that there were such installations. The ratio in the Hell Gate Station just referred to was 85.7.

In putting the castings on to the tubes there is no machining of the tubes. It is a cold drawn carefully sized tube. The cast iron is carefully bored to gauge. The external

heating surface of the ribbed element is three square feet per 175
lineal foot. The internal heating surface of a 2 inch tube is .524 square feet per lineal foot so that the ratio of the external to internal heating surface is slightly less than 6 to 1.

The ratio of external heating surface per cubic foot of space occupied with the Foster economizer, when not allowing for the staggering of the tubes, is 14.64. Allowing for the staggering of the tubes the ratio would be slightly less.

I do not think that in the vertical tube economizers, which were practically the only types of economizers used before Bell, the counter-flow principle was applied to the same extent that it was by Bell. It was well known that counter-
flow was a desirable principle, but the construction had not 176
been worked out, if my recollection is correct, to obtain it to as great an extent as Bell does. In the vertical tube economizer the gas entered at the opposite end from the cold water, but each successive tube did not receive successively hotter water. It was divided into groups as a rule, so that in one group of tubes near the cold end the water temperature entering would be the same. Then it would leave that group. The water temperature entering the next group of several rows of tubes would be all the same. But in Bell's each row received successively water at a hotter temperature.

Prior to my examination of the economizers of Exhibits
Nos. 5 and 6, I had seen horizontal tube economizers other 177
than the Bell economizer. I had seen the Babcock & Wilcox economizer at other places and some Sturtevant economizers at Hell Gate. I was familiar with the horizontal tube economizer possibly a year before the date of the Bell application. This was an economizer that the Power Specialty Company was developing. I think the Babcock & Wilcox economizer first came before the public at about the same time.

The plaintiff manufactures and puts out what is known as

178 the Foster superheater and has been putting it out for at least 20 years, possibly longer. This Foster superheater is correctly illustrated and described in the catalogue marked "Superheated Steam, Foster Superheaters" (Defendant's Exhibit B). Mr. Bell was consulting engineer for the Power Specialty Company from about 1915 until the time of his death, about 1925. Prior to his connection with the Power Specialty Company he was connected with the Babcock & Wilcox Company.

[Counsel for defendant offers in evidence the Foster Economizer Catalogue as "Defendant's Exhibit A" and the Foster Superheater Catalogue as "Defendant's Ex-
179 hibit B".]

Redirect Examination by Mr. McKnight.

The 15 installations of economizers having tubes 8 feet long were all in industrial plants. The plaintiff had not used as short a tube as that in power plant work. The minimum in power plant work was not less than 10 and probably not less than 12 feet.

[Counsel for plaintiff offers in evidence the document containing the specifications issued by U. G. I. Contracting Company for economizers at the Devon plant of Connecticut Light & Power Company at Devon, Connec-
180 ticut, together with the bid of B. F. Sturtevant Company and the contract between U. G. I. Contracting Company and B. F. Sturtevant Company, the whole document being marked "Plaintiff's Exhibit No. 7".]

Defendants' Proofs. 181

ARTHUR S. BROWNE, a witness called on behalf of the defendant, having been sworn, testified as follows:

Direct Examination by Mr. HILDRETH.

I live in Washington, D. C. and am a mechanical and patent expert. I graduated from Dartmouth College in 1881, and in the following year I entered my present profession, in which I have been since actively and continuously engaged. I have prosecuted many hundreds of applications for patents, but during the last 35 years the greater portion of my time has been taken up in testifying as a mechanical and patent expert in litigations involving patents covering the entire 182
United States and Canada and the Court of Claims in the United States. I have testified in many more than five hundred such patent cases and have been in suits on behalf of the United States Government, many of them in the Court of Claims and other courts, and also for the Canadian Government. I have been acquainted with the subject of boilers and heaters for many years, having represented such concerns as the Erie City Iron Works, manufacturers of boilers, and the Fownes Company. I have given particular consideration to the subject-matter of the present litigation and have informed myself regarding the matters in issue, the 183
structures of the plaintiff and of the defendant, and also have investigatad the prior art relating to the subject.

[Counsel for the defendant offers in evidence the following Letters Patent which are marked respectively as indicated.

Foster Patent No. 744,323, as "Defendant's Exhibit C".

Kablitz Patent No. 886,516, as "Defendant's Exhibit D".

Foster Patent No. 963,732, as "Defendant's Exhibit E".

184 Foster Patent No. 1,239,377, as "Defendant's Exhibit F".

Keenan & Thomas Patent No. 1,282,851, as "Defendant's Exhibit G".

French Patent to Dietrich No. 237,583, as "Defendant's Exhibit H".

Counsel for defendant also offers in evidence a translation into English of the Dietrich French Patent, as "Defendant's Exhibit I".

British Patent to Davies No. 7733 of 1908, as "Defendant's Exhibit J".

British Patent to Simon No. 412 of 1873, as "De-
185 fendant's Exhibit K". The Simon patent is offered to show the state of the art.

It is stipulated and agreed that the translation into English of the Dietrich patent, "Defendant's Exhibit H", is a true and correct copy, subject to correction from the original certified copy.]

Comparing the patents which have have been introduced in evidence with the subject-matter of claim 2 of the patent in suit, I will refer first to the French patent to Dietrich, No. 237,583, of 1894. There are three sheets of drawings illustrating three different apparatus, sheet 1 representing a water
186 boiler, the second a steam boiler, and the third an economizer, or, as the French has it, a re-heater for feed water for a steam boiler; and it is to this third figure I will pay especial attention.

This drawing illustrates a bank of tubes through which the water passes which is to be heated, and this bank of tubes is composed as illustrated of twenty horizontally extending water pipes arranged in five rows one above each other, each row having four pipes. This economizer, consisting of these water tubes, is placed in a flue or passage-

way leading from the steam boiler, of the character illus- 187
trated in the preceding sheet of drawings, so that the spent gases of combustion coming from the boiler pass through and around the economizer for the purpose of heating the feed water. The water is introduced in this case at the bottom and then passes upwardly and lengthwise of the several water tubes, and ultimately the feed water passes out of the top, while the gases that come from the left hand pass up and to the right, so that the water passing through these various pipes of the feed water heater is heated by the gases.

It will be noted that these pipes run horizontally, and also that each of them is equipped with a series of discs or ribs for the purpose of giving a greater area to the hot gases for 188
the purpose of transmitting the heat to the water inside. Also in addition to the main discs, or the discs which are greater in number which are circular as indicated in the figures at the right, there are larger square discs both at the middle at A and at each end B and C, which entirely fill the spaces between the pipes so as to thereby constitute a partition in the middle to direct the gases, and also partitions at the ends to keep the gases directly away from the joints of the pipes where the various pipes are connected to each other at their ends.

I wish now to call attention to the specification which re- 189
fers to those pipes or discs. The language of the French is really "pipes with little wings". I presume the word "Ailette" really is a wing,—"with wings". They sometimes use the expression "fin". The specification says, I quote from the translation Defendant's Exhibit I:

> "Tubes provided with disks may be used for water heaters or boilers if one arranges them in groups side by side or one above the other forming the arrangement which presents to the flame or to the hot gases, whose

190 heat is to be absorbed, the desired amount of heating surface; and if one arranges them in such way that the water to be heated circulates inside the tubes from the lowest point to the highest. Such disked tubes will permit the assembly of a very considerable heating surface in a small volume and permits the arrangement of boilers in very restricted space."

That is to say, the purpose of utilizing these pipes with the discs on them is for the purpose of getting a very considerable heating surface in a small volume, so as to permit the apparatus to be installed in a restricted place, which is
191 the exact purpose of the device of the patent in suit, which has already been explained to your Honor. That is to say, the effect of putting these discs or rings on the pipes is to give each pipe an extended surface where it is subjected to the gases. That is, a pipe with these rings on it may be two or three times the area which a plain pipe may have.

The COURT. Exactly the reverse of what it was in the old days of automobile radiators that had pipes with fins on them for the purpose of cooling the water, and they are now used for heating them?

Precisely, in either case. It is quite common to use the same sort of organization either for cooling or for heating,
192 and an ordinary heat radiator for the heating of rooms is made in a similar way. They have been provided with discs for the purpose of providing an extended surface to heat the air in the room. So that is what this French patent does. It gets an extended heating surface for the hot gases, and as the result there is an increased heating surface within a given volume of space so that it is thereby possible to put the apparatus in the limited space available In order to facilitate explanation of this French patent, and comparing it with claim 2 of the patent in suit, I have had a perspec-

tive drawing made showing the wings or discs on only one 193
of the pipes. It should have wings on all of the pipes but that would be rather confusing.

Compare this with claim 2. Claim 2 recites: "The combination with a boiler and its furnace", and a boiler and a furnace are shown on the other figure of the drawing in the French patent, "of an economizer comprising a bank of horizontally disposed tubes"—that is the bank of the horizontally exposed tubes [indicating]—"externally swept by the heating gases leaving the furnace and through which feed water is passed into the boiler, said tubes being each provided with external circumferentially extending ribs"—which these have—"proportioned and disposed to make the exter- 194
nal surface area of the tube several times greater than its internal surface area"—which is obviously true of the construction, when the internal diameter of the tube is compared with the external surface with its ribs. Then, the claim goes on to say: "and being each of a length many times greater than its maximum diameter".

And in this case the length of the tube is greater than its maximum diameter. I will take up the "many" in a moment.

> "and being each of a length many times greater than its maximum diameter and being spaced to provide an 195
> external tube surface area per unit of space occupied by said bank which is several times greater than is practically possible with tubes which are of the same internal diameter and have smooth outer walls."

Note in this case particularly, with reference to the cross-sectional view at the right of sheet 3 of the drawings of the French patent, that the tubes are just about as near together as they can be, both horizontally and vertically considering the diameters of the discs and headers, so that for

196 the same reason as in the plaintiff's apparatus, because you have got the discs on the tubes and because the tubes are placed nearly as close together as they can get by reason of the diameter of the disc and by reason of the necessity for leaving space for the passage of the gases, there is necessarily in the French patent in construction a much greater area of heating surface than there would be if only plain tubes were employed.

Accordingly this French patent discloses the subject matter of claim 2 unless indeed there is some limitation to be placed on the word "many".

The claim calls for "a tube being many times greater
197 than its maximum diameter", but the specification gives no reason for doing so; in fact, the specification does not use the word "many" at all, and it can only be judged what the patentee means, because his drawing shows his tubes to be about 30 times longer than their maximum diameter. Of course, the word "many" is used in very widely and different senses. For example, Joseph had a coat of many colors, and the United States has many people in it.

In connection with this particular matter, I also call attention to the fact that the specification of the French patent at the bottom of page 2 of the translation says:

198 "These pieces of apparatus are indicated merely to show the practical form of the use of disked tubes and of the use of tubes provided with the special disks A, B and C, confining the gases in their path across the group of tubes forming the boiler and protecting their joints, and also to show the utilization of boilers so obtained for heating water or for the production of steam, but it is quite evident that other forms and arrangements in assembly or in the details of these pieces of apparatus may be used in order to meet the convenience of installation."

That is to say, as I understand, the drawings show the

principle of the apparatus and this principle is to be utilized 199
depending upon the particular nature of the installation.

Also there is one other suggestion which the French patent says, and that is, as illustrated, each pipe has a four-branched end or cross as the specification says, so that there are three connections from the pipe itself. One of these connections goes to the header above for the top row and goes down with a flange connecting it to the lower tube, and so on, and at the outside in the third connection is a cap which can be taken off for the purpose of getting in apparently to clean the tubes; but the specification says in this connection:

> "The usual disked tubes, as well as the tubes with 200
> special large disks A, B and C, used in these pieces of apparatus, will commonly have the form of a cross at their ends, but we reserve also the right to give them the usual flange form at the ends. In this case, the tubes would be connected by 180 degree bends when grouped to form a boiler."

I understand what the patent means at this place by the usual flanged form at the ends with the U connection, is such a construction as was well known at the time, which is illustrated, for example, in the British patent of Simon, numbered 412, February 4, 1873; and I direct attention to the
economizer which is shown on sheet 3 of the drawing of this 201
patent, and in Fig. 21, 22 and 23, and which is described in the specification beginning at line 17 at page 12.

I simply call attention to the fact that in this economizer with horizontally extending tubes arranged in rows and also staggered as illustrated in Fig. 22, the pipes are connected at their right-hand ends, as shown in Fig. 21, by flanges on the ends of neighboring pipes, these being connected by a 180 degree or U bend.

It will also be noted from this patent that the water pipes are very much longer than their maximum diameter.

202 I have called attention to the circumstance, in this economizer of the French patent, that the water enters in the bottom and goes out at the top; but it was old in the case of an economizer having horizontal tubes, or substantially horizontal tubes, for the water to enter at the top and go out at the bottom and in the opposite direction to which the gas flows, such being known as a counter-flow organization, and to illustrate that I have selected the British patent to Davies No. 7,733 of 1908.

The economizer is illustrated in connection with the boiler and furnace in Figs. 1 and 2 of Davies. Referring to Fig. 1, the specification says, beginning at page 6, line 20:

203 "As shown in Fig. 1 an economizer 27 may be provided on the top of the boiler in which case the headers are preferably arranged horizontally instead of vertically. The feed water enters the economizer through the inlet 28 and passes to the drums and steam generating tubes through the feed outlet 29, the said feed outlet being preferably formed by a rising pipe, as shown, in order to prevent the economizer from being emptied by gravity.

It will be seen that this arrangement allows the feed water to enter at the top and gradually get heated up as
204 it travels down to meet the hotter gases of combustion."

In other words, it is a counter-flow organization, the water flowing down back and forth through the nearly horizontal tubes while the hot gases flow in the opposite direction.

Note in this construction, as shown in Fig. 2, that the nearly horizontal pipes extend back and forth between headers at the opposite ends, that is, the header being a long box and hollow so that the pipes extend from box to box back and forth, so that while the general flow is nearly horizontal, ultimately the water passes from the top to the bottom. I might say that this is an arrangement very much like that

of the Babcock & Wilcox organization shown in Plaintiff's 205
Exhibit No. 6.

In this Babcock & Wilcox exhibit, as explained by plaintiff's witnesses, there is a series of headers at the opposite sides connected by the numerous small pipes, so that the feed water, which in this instance feeds up, because the gas goes down, starts at the bottom, and goes from the lowermost header at the left, across to the right and back and forward, and back and forth, and so on, up to the top where it is discharged, of course the water passing through the various groups of pipes as the case may be, which is just the arrangement which Davies has, as far as the back and forth flow be-
tween headers is concerned, and being a counter-flow arrange- 206
ment, except as I say while Babcock & Wilcox have the water go up and the gas down, Davies has the opposite arrangement.

I next call attention to the United States patent to Kablitz, No. 886,516, May 5, 1908.

Note by reference to the drawings of this Kablitz patent, particularly Figs. 1, 2 and 4, that the pipes of this feed water heater or economizer are ribbed tubes or disked tubes, just as in the Dietrich patent to which I have already referred.

The patent says that such ribs present an extended surface. For example, at page 1, beginning with line 106, the 207
specification says:

> "The ribs on said pipes present surfaces, which collectively speaking are of a relatively great area, and said surfaces rapidly collect portions of soot from the products of combustion and as they lose their efficiency when coated with soot it is essential to clean the same."

At page 2, beginning with line 21, it says:

> "Throughout such courses the water is subjected to the action of a relatively extensive heating surface since the exterior portions of all the pipes, connections, and

208 the bearing portion A are subjected to the action of the products of combustion."

So that is why he has his ribbed tubes, namely, because they present an extended area to the smoke and gases from the furnace and a relatively small internal surface for the water which is to be heated.

As will be noted from Figs. 1 and 2, these tubes with their discs or ribs are much longer than their maximum diameter, and also that the pipes are placed closely together so that there is a large amount of heating surface. Also, these pipes are staggered in respect to each other as is best indicated in Fig. 3.

209 Looking at Fig. 3 there are certain circles there that are shown at F^1 to F^5, which are not pipes, which overlie spaces which are left for devices for removing the soot. The intermediate row of ribbed pipes or disc pipes is staggered with respect to the two outer rows.

Of course, it follows that by reason of the ribs on the pipes or the discs on the pipes, they have an external area several times greater than the internal area.

Of course, Kablitz shows these pipes as extending vertically and not horizontally, which I think is the only recitation in claim 2 of the patent which distinguishes it from the structure of this Kablitz patent.

210 The specification of the patent in suit refers at page 1, line 46, to the " well known Foster superheater ". At this point it says that he employs a tube " similar in construction to those heretofore employed in the well known Foster superheater, in that each tube comprises an inner tube of wrought steel which is surrounded by an externally corrugated tubular cast iron casing ". So that so far as the steel pipes with the outside discs are concerned, they were simply utilized as Foster had already used in a superheater.

As illustrating the Foster superheater, I first refer to the Foster patent, No. 744,323, November 17, 1903.

There is a Foster superheater patent, No. 963,732, July 5,

1910, illustrating the way in which the pipes with their discs 211
can be organized in order to make a superheater. The purpose of the superheater is to heat the steam which has already been formed in the boiler so as to make it dry. It is illustrated in Fig. 1, which shows the rib tubes in longitudinal section. Also, it is shown in cross-section in Figure 3, there being a similar group of tubes on the other side.

Note that those tubes are many times longer than they are wide, and that they are arranged horizontally and in layers or groups. Also, a similar organization is shown in the Keenan & Thomas patent, No. 1,282,851, October 29, 1918, assigned to the Power Specialty Company on its face. As illustrated in
Figure 1 of the drawings in the patent, the superheater is 212
shown in the uptake, and there the tubes are shown as rib tubes arranged horizontally, each tube being much longer than its maximum diameter.

Referring to the patent of Foster, No. 1,239,377, September 4, 1917, note that Foster applied his own tubes, with their rib wings or discs on them, for the purpose of constituting an economizer. Also in his economizer he feeds the water in at the top, it flows down through the various ribbed tubes or disc tubes, to the bottom, whereas the gases from the boiler pass upward in the opposite direction so that it is a counterflow apparatus, with the water flowing downwardly while
the gases flow up. 213

Foster illustrates this organization in connection with a peculiar sort of boiler; that is, his boiler is made up of many separate sections. Each section of his boiler comprises two vertical headers with intervening tubes, placed across. One rank of his feed water heater, that is, one section of the pipes as illustrated in Fig. 1, serves the same section of the boiler. His boiler is made up by having a number of those boiler sections, and feed water sections, arranged parallel to each other.

I have a model here, which illustrates what I understand to be the construction shown in the Foster patent. Note

214 that there are shown twelve boiler sections. The feed water heater is made up of a corresponding number of sections here shown in metal, there being one vertical rank of pipes with discs for each of the boiler sections. So if there are twelve boiler sections as illustrated in the model, there will be twelve sections of the economizer. Note that the economizer in the model is illustrated with discs on it so as to form an extended surface.

Regarding the economizer by itself, aside from the question of the peculiarity of the boiler, it provides horizontal disposed pipes with the water feeding downwardly, and the gas feeding upwardly, and each pipe has on it these ribs or
215 discs so as to give an extended area to it, thereby getting a heating capacity, since much more of the area of the pipe is subjected to the hot gases.

The only thing that I can see that Foster lacks of the subject matter of claim 2 of the patent in suit is that Foster does not have his tubes relatively as long as in the patent in suit.

Excepting for the force to be given to the word "many" in claim 2, regarding the length of the ribbed pipes, the Foster economizer of this Foster patent has the subject matter of the second claim of the patent in suit.

While the Kablitz tubes extend vertically, the gas flow is
216 between and through those pipes, and generally speaking in a horizontal direction. I do not find anything in the specification which indicates whether that flow is from right to left or vice versa. It does not say. It does not say if it flows at right angles.

The large drawing entitled "Dietrich French Patent No. 237,583", which I have referred to, correctly illustrates, in a general way, the construction shown and described in that patent. I have not checked up their exact measurements but it illustrates the principle.

[Counsel for the defendant offers in evidence this drawing of the Dietrich patent as "Defendant's Exhibit L".]

The two large drawings entitled "Kablitz Patent No. 886,- 217
516" correctly illustrate the construction shown and described in the Kablitz patent, one in perspective and the other in cross-section.

[Counsel for defendant offers in evidence the perspective drawing as "Defendant's Exhibit M" and the sectional drawing as "Defendant's Exhibit N".]

The drawing marked "Foster Patent No. 1,239,377" correctly illustrates the construction of the Foster patent.

[Counsel for the defendant offers in evidence this perspective view of Foster patent No. 1,239,377 as "Defendant's Exhibit O".]

The large drawing marked "Bell Patent No. 1,565,305", 218
correctly illustrates the principle of the Bell patent. Only a portion of the rings are shown, the others being left off in order to facilitate the showing of the arrangement of the pipes.

[Defendant's counsel offers in evidence this view of the Bell patent as "Defendant's Exhibit P".]

The model of Foster patent No. 1,239,377 correctly illustrates the construction shown and described in that patent. While the drawing of this patent shows no more than three of the boiler sections, nevertheless as I read the patent there are to be a large number of these sections and accordingly the model shows 12 of them.

219

[Counsel for the defendant offers the model in evidence as "Defendant's Exhibit Q".]

The model illustrating the construction of economizer of the Bell patent in suit represents that construction so far as the economizer is concerned.

[Counsel for the defendant offers the model in evidence as "Defendant's Exhibit R".]

Another model illustrates the economizer made by B. F. Sturtevant Company illustrating the ribbed tubes. It will be noted that the header for the upper set of pipes is connected by a tubular connection to the third header and with

220 the third series of pipes. That is to say, the odd numbered set of pipes throughout are in one circuit, and the even numbered set of pipes are in the second circuit. This model is substantially accurate.

[Counsel for defendant offers the model in evidence as "Defendant's Exhibit S".]

Cross Examination by Mr. McKnight.

The model Defendant's Exhibit S, I understand, is a model of the defendant's economizer installed in the Devon plant. I do not know it to be the case. It is like those made by the Sturtevant Company that I have seen, and I have been advised that it is the same as what has been installed in the Devon
221 plant. I do not know of my own knowledge that this model gives the precise proportions in the actual plant at Devon.

I have never been actually connected with concerns engaged in the manufacture of economizers at any time except such services as I have done here. I have never been an engineer of design or construction. From 1890 to 1900 I was not familiar from practical experience with the construction of economizers, but I had a very general knowledge of it at that time from study and reading of literature.

Referring to the three Foster patents which have been discussed, I find no specific statement with respect to the spacing of the tubes, center to center, in a horizontal row, only
222 what can be judged from the drawing. The same is true with regard to the spacing of the tubes, center to center, in the vertical rows; that is, there is nothing in the text. I do not find in either of these three Foster patents any statement relative to the employment of high draft suction through the economizer tubes.

[It is stipulated between the parties that the stenographic costs of the copy of the record for the court shall be paid equally by plaintiff and defendant, and on taxation shall be recovered by the winning party.]

ERNEST B. FREEMAN, called as a witness on behalf of the defendant, having been duly sworn, testified as follows: 223

Direct Examination by Mr. HILDRETH.

My name is Ernest B. Freeman; I live at No. 70 Hunnewell Avenue, Newton, Mass. I am fifty years old, and am vice president and general manager of B. F. Sturtevant Company. I have been connected with that company since January, 1903. At first I was engineer and field superintendent for the economizer department, in the fall of that year becoming head of the economizer and mechanical draft department. On January 1, 1907, I was appointed sales manager, and a year later was appointed acting manager. Eight months later in that year I was made general manager, and for the last ten 224 years I have been vice president. B. F. Sturtevant Company is defending and controlling and directing the defense in this suit.

Prior to my connection with that company I was with the Boston Rubber Shoe Company as assistant to the chief engineer for a few months, and in November, 1901, went with the Green Fuel Economizer as draftsman and fieldman and engineer, and later did testing and sales work. This company was the largest manufacturer of fuel economizers.

I am a graduate of the Worcester Polytechnic Institute of Worcester, Mass., receiving the B. S. degree in 1901 in the mechanical engineering course, and at present am a trustee 225 of that institute. I am a member for my company of the Power Club, which is an electrical engineering association; also of the American Heating and Ventilating Society, the Stoker Association, and the A. E. E. I. Association, which is an electrical association.

Since I left the Worcester Polytechnic Institute in 1901 practically all my engineering work has been in connection with steam engineering, power plant work. With the United States Rubber Company I was testing and superintending the erection of new power apparatus that they were purchasing, and with the Green Economizer Company I was super-

226 intendent of the installation of economizers, and installed them, and later sold and engineered their application. When I went to the Sturtevant Company I did installation work for a while, and designed and patented and installed and sold economizers. I have taken out several patents on cast iron type of economizers.

I am familiar with the general principles and theories of economizer construction and operation. The fundamental requirements or requisites of an economizer have been known for seventy-five years. They may be summed up as three, a large amount of heating surface to receive the gas temperature, definite circulation of water, and keeping clean.

227 For the first sixty or seventy years the economizers were made entirely of cast iron. This was considered necessary for several reasons. The first was, that cast iron was the best known cheap metal that would resist corrosion which is always present in an economizer installation. From then on, steel tubes have been used with cast iron headers, with steel headers, and with forged steel headers.

Corrosion takes place both internally and externally. External corrosion is generally the more serious for the reason that all coal contains more or less sulphur, and any moisture in the economizer chamber combines with the sulphur, causing sulphuric acid. Internally the corrosion is due to air or
228 oxygen in suspension, and it corrodes from the inside both headers and tubes, but more particularly the tubes.

In cast iron economizer design there was not a great deal of trouble from corrosion due to the resistance that cast iron has to sulphuric acid and to the air. In certain installations where the sulphuric acid was very strong, considerable of it, there was more difficulty from external corrosion. In steel tube machines there is always difficulty if sulphuric acid is present, or if air or oxygen are liberated in the water, because steel does not resist either one.

Cast iron economizers have been cleaned largely by me-

chanical scrapers which work automatically and scrape the 229
soot or ash from the outside of the tubes. The inside of the tubes where scale is formed are cleaned largely with small rotating knives. More recently the soot blower has been used. These have been known for a great many years but economizer manufacturers were afraid to use them because they introduced more moisture into the economizer chamber and this moisture united with the sulphur to form sulphuric acid. As the soot blowers were improved, and as drier steam was used in them, they have been generally adopted for cleaning the outside of the economizer pipes.

B. F. Sturtevant Company has been manufacturing and
selling economizers for over 25 years. After the first three 230
or four years, that is, in 1905, we sold and installed more economizers than anyone in this country or Canada up to the advent of the steel tube machine after the war. From then on the business has been divided into two classes, the steel and the cast iron. In the steel field the Babcock & Wilcox Company have materially predominated in the volume of business done. In the cast iron field we have continued to hold our leadership. Babcock & Wilcox Company have always used plain tube economizers.

B. F. Sturtevant Company has sold and installed econo-
mizers all over the world, but by far the largest volume has 231
been installed in this country and in Canada. The first design of the Sturtevant Company was a cast iron machine with pipes arranged in straight rows, and the pipes having a taper metal-to-metal joint, but gaskets were used for other joints. In 1903 I re-designed the machine and used staggered pipes and eliminated all gasket joints so that all joints were taper metal-to-metal. In 1906 we designed and sold what we called a pony economizer which was made of 2½ inch cast iron pipes and without scrapers. In 1910 we tried to use Spellerized steel tubes with cast iron headers, and installed a job at the Maverick Mills in Boston. In 1922 after we discovered the lead coating process, we designed the plain

232 steel tube economizer with cast iron headers. Then later the plain steel tube with cast iron steel headers, and then in 1924 the so-called Y-type with the discs as you call them.

The Spellerized pipe or tubes was a patented tube put out by the United States Steel Corporation and designed to resist the sulphuric acid action and the action of air inside the tubes. These tubes which were used in the Maverick Mills at East Boston lasted but a few months and had to be replaced with cast iron.

The reason for adopting the steel tube economizer following the cast iron economizer was because the boiler pres-
233 sures were mounting so high. The customers felt that the cast iron was not safe and there was more breakage.

The water pressure in the economizer is slightly higher than the steam pressure in the boiler because the water has to be pumped through the economizer and through a check valve into the boiler. Where the pressure is 250 to 300 pounds and over, cast iron is not as safe as steel, and there is considerable breakage due to the high pressure. A great many installations employ pressures of 400, 500 and 600 pounds, and pressures have even gone as high as 1,400 pounds. Therefore it became necessary to use material stronger than cast iron.

234 The increase in boiler pressure has been gradual for 50 years. When I began to study the art it was not unusual to install an economizer for 80 to 100 pounds of steam pressure. About 1906 to 1908 it was 150 to 200 pounds; just before and during the war it got up to 250 pounds; then the development was increased to 300, 400, 500 and 600 pounds, about 1918 to 1920. It is now used as high as 1,400 pounds in some of the large stations, but not regularly.

The lead coating process employed by the Sturtevant Company was brought to us for coating fans to prevent corrosion and deterioration when used in acid plants and the like. It is a secret process and I saw that it could be used for econ-

omizers with steel tubes which we had wanted to use but 235
could not do so sooner. All surfaces that are exposed to water or gas are coated both inside and out. The two sections of pipe with discs on them are our steel pipe with steel rings. One section is uncoated and the other has our lead coating on both the inside and the outside.

[Counsel for defendant offers in evidence the two sections of pipe, the uncoated section as "Defendant's Exhibit T", and the coated section as "Defendant's Exhibit U".]

This coating has proved a satisfactory protective coating. We have had no trouble whatever except where the hot gases have been allowed to pass through the machine when it was 236
not filled with water, and where leaks in the economizer header have permitted the water at this high pressure to spurt out against the tube, and the water has gone right through the coating and the tube as it always will. Where there have been no leaks and the water has been kept in the machine there have been no difficulty.

After our experience with the steel tubes in the Maverick Mills in 1910, we did not use steel for some little time because we felt confident it would not stand corrosion, and it was not until 1922 that we found the lead coating. We had, however, been interested continuously in steel tube econo-
mizers. We tried to find a steel. We sent a man abroad in 237
1920 to determine what had been worked out there. We thought possibly there might be a stainless steel or some other steel that would be commercially possible to use. While he was there we had him investigate in England and through Europe, and he did find a steel tube economizer which was installed so that about a third of the sections on the cold end could be removed every two or three years readily, because the designers and manufacturers appreciated that it would not withstand the corrosion, and they had had the same experience that we had had. We had some negotiations with these people with the idea of purchasing the American rights, but then we

238 felt that customers would not receive kindly this idea of replacing a third of the machine every two or three years, or whenever it was necessary, and then we discovered the lead coating, which prompted us to build this design with the coating.

Lead coating was called to our attention in July, 1922, and we immediately began experimenting with it to adapt it for steel tube economizers. We had to modify it to secure the desired results. It was first used on the type X steel tube economizer with plain tubes like that shown in Plaintiff's Exhibit No. 5. In that exhibit the headers are shown vertical but our type X machine was made with headers both ways, both vertical and horizontal. This type X machine is the
239 same, except in minor dimensions and the fact that it has the plain tube, as the Connecticut Light & Power machine with discs on the tubes complained of as an infringement in this suit. This type X has gone into commercial use and a great many have been sold. We have just completed an installation of five machines at the Detroit Municipal Plant. The results secured with this type X machine have been very satisfactory. The first type X machine was sold in March, 1923, and shipped the following June.

Following the type X machine our company put out the type Y machine in controversy in this suit. After we had found that the lead coating was successful, I told Mr. Derry, who
240 was the head of the economizer department, that as boiler and power plant designs were developing, space was being limited continuously, and it would be necessary to work out an extended surface type of machine; and he and the engineers went to work on it, and investigated at the time such surface as had been used for thirty years on house radiaiors, the automobile type of surface which had been used for twenty-five years, the surface similar to the airofin and superheaters. His first experiment resulted in the shrunk or ring method which was not satisfactory because to obtain efficient extended surface you must have definite constant, continuous

contact. We then purchased a patent which covered this 241
expanding of the tube into the discs which we are using, which seemed to us and has proven to be the best method of contact we have found. The discs on the tubes of this type Y machine were for the purpose of obtaining more heating surface within a given space. They are not as efficient as the bare or "prime" surface of the tube because of the difficulty in getting a definite contact between discs and tube through which the heat must travel. The only prime surface we have lost is where the disc is attached to the pipe. This method of securing the discs on the tubes which we are using came to us on the first of December, 1924.

Our company has used extended surface for a great many 242
years. We have used it on what we call our hot blast heaters. As manufacturers before and during the war, we had used it for the cooling of aeronautical motors. We have used it on gasoline engine generating sets for at least fifteen years, and also in our drying work, where the saving of space was necessary. Extended surface was old with us in our own practice.

I am familiar with superheaters in a general way, having seen them in catalogues ever since I have been in this work. Babcox & Wilcox Company in 1901 was making a plain tube superheater.

Economizers are designed for every job. They are cus- 243
tom made. The size, dimensions, and arrangements of these economizers are determined by the boiler horse power and the space available, the location of the boiler, the stack or chimney if they use one. The boiler horse power, of course, determines the amount of gas that must be passed through the economizer, and also the amount of water that must be passed through.

Long tubes are cheaper to manufacture than short tubes because they require less headers and connecting bends for

244 the same amount of heating surface. Long tubes are cheaper to maintain because there are less joints. The duct or gas flue leading from the economizer to the boiler is, generally speaking, rectangular, and a little longer in one direction than in the other. There are any number of designs in use and possible. The economizer manufacturer would generally prefer to extend his tubes the long way of the duct, which is the way they are arranged in defendant's economizer at Devon.

The Sturtevant Company began to manufacture economizers with horizontal tubes a great many years ago. In 1916 there were installations made in the Barrett Company.
245 A great many have been put in. It is similar to type X except that cast iron pipes and horizontal headers were used. These horizontal tube economizers are shown in one of the company's drawings which I identify.

[Counsel for defendant offers the drawing in evidence as "Defendant's Exhibit V".

It is stipulated that the original drawing may be withdrawn and a blueprint substituted.]

This drawing shows two elevations and a plan. It shows the sections in place with their steel supports similar to our present Y type series of supports. It shows the connections
246 between the headers, and it shows the way the headers themselves are divided up to direct the water, and it shows the circulation of the water. The right-hand figure of this drawing is a side elevation showing the sections and headers in the same position as in Fig. 2 of the Plaintiff's Exhibit 2. An economizer was built as shown in the drawing and the gas went in at the top and came out at the bottom, and the water was up flow, first through one pipe in the lower section and then to the next section, etc. It was a counter flow economizer.

For the same duty the Sturtevant type X economizer with

the plain tube cost more to build and, therefore, more to the 247
purchaser, than the type Y because for the same amount of heating surface more headers and connections are required in type X than in type Y. There is no fixed rule with regard to certain makes of economizers being used with certain makes of boilers. A great many customers of Babcock & Wilcox Company insist that they want Babcock & Wilcox economizers when using their boilers. We sell our economizers for use with Babcock & Wilcox boilers.

The first installation I know of where the boiler pressure and economizer pressure was 1,200 or 1,300 pounds was at the Edgar station of the Edison Electric Illuminating Com-
pany of Boston, which I have personally visited. Both the 248
Power Specialty Company and Babcock & Wilcox economizers are used there, the Babcock & Wilcox economizers being used with the higher pressure boilers.

The draft loss in economizers is the resistance to the velocity of the gas in passing it through a congested chamber filled with pipes. This resistance is overcome by a suction created at the outlet of the economizer, either by a chimney or an induced draft fan. When I first went to the Sturtevant Company very low velocities were used. Gradually as greater duty has been required from power plants, this velocity has been increased until now it is not unusual to
install very high velocity apparatus that will produce very 249
high velocities. Low velocity of the gas might be under one thousand feet per minute, while high velocity might be as high as ten thousand. I can give some figures for economizer draft losses corresponding to these velocities. In old installations, where velocities were low, I have measured draft losses in an economizer as low as a quarter of an inch. Today I do not know how high they go, probably as high as at least four or five inches. The suction or pressure in air engineering practice is measured by what we call a water

250 column. A tube is placed on one end of a U-shaped column and the suction or pressure quite naturally brings that column to an uneven position. The difference in the level in the two columns measures the suction. It corresponds to what might be called a very sensitive barometer.

There was a very gradual increase in these draft losses or suctions up to 1913, but not a radical increase. In 1913 we materially increased the suction and velocity. A particular installation I have in mind was a large installation at the Commonwealth Edison Company of Chicago, sold through Messrs. Sargeant & Lundy, consulting engineers. In that installation the draft loss through the economizer was nearly
251 three inches, between two and a half and three inches. It has been the practice of the Sturtevant Company to regulate or control the velocity of flow through the economizer. This is very definitely figured and the desired velocity is secured with the fan.

The water is controlled and its flow determined in a great many ways. First, we have what we call the natural flow which means that the water goes in to a wall box or branch pipe at the cold end of the economizer and at the bottom, and flows against the course of the gas through every section or whatever course the resistance prompts it to take to the outlet at the hot end of the economizer, which is at the
252 top. That is the so-called natural circulation, no attempt being made to direct its course. That is true of both horizontal and vertical economizers. Then there is the circulation which has been used a great deal, and especially in cast iron economizers, of circulating the water up a few sections, possibly eight, down four, up eight, and so on. There is the additional circulation of through one section and into the next, and so forth. Then there is still the further circulation as shown in this drawing of through one pipe, that is through all pipes in series, but always counter to the flow of the gas.

In Defendant's Exhibit V the division baffles in the headers 253
are indicated in dotted line. Their purpose was to force the water through one tube, then through portions of the header to the next tube, and so on. The water passes in series through the tubes. Such baffles were a common expedient in controlling the velocity of the flow. A vertical tube economizer in which the up flow and down flow was through portions having different numbers of sections is shown in Sturtevant drawing C15-5088-P. This is one of our standard diagram drawings showing various circulation methods and methods of connecting the pipe to the economizers.

[Counsel for defendant offers in evidence this drawing as "Defendant's Exhibit W", and it is stipulated that 254
the original may be withdrawn and a blue print substituted.]

Constructions such as shown in this drawing were sold by my company to American Gas & Electric Company, Windsor Bath Station, Beach Bottom, West Virginia. There were three of these, the first one in the latter part of 1915 judging from the order, the drawing being dated 1916. The upper left-hand figure of this drawing shows that the water went up in ten sections, down two, up six, down two, up eight, down two, up six, down two, up six, down two, up six, down two, and then up ten. The effect of passing the water down- 255
wardly through a fewer number of sections than the upflow was to increase the velocity and, therefore, the heat transfer. The flow of gas is contrary to the flow of water and across the tubes.

I have examined the drawing of the Kablitz patent, Defendant's Exhibit D, and understand the construction and operation of the economizer illustrated. There is no difference in the function or effect of the discs in the Kablitz economizer from that of the discs in the defendant's economizer. That function is more heating surface in the same space and

256 to transmit the heat from the gas to the water in the economizer.

Nor is there any difference in function between the effect of the discs on the tubes of the economizer of the Dietrich patent, Defendant's Exhibit H, and the effect of the discs on the tubes of the defendant's economizer. The Dietrich tubes are larger apparently. The defendant secures no advantage whatever by the extended surface or discs of these economizers as distinguished from the advantages secured by Dietrich and Kablitz from the extended surface of those economizers, unless in some degree depending on the sizes of the pipes and discs.

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Cross Examination by Mr. McKnight.

I am familiar in a general way with Plaintiff's Exhibit No. 4, which is Sturtevant Bulletin No. 334, and with its text. So far as I know the statements in the bulletin are true and correct. I have never gone over them carefully. My company would not willingly put out for public use a bulletin which had not been carefully examined and which contained any statements known to be incorrect. My company distributed the catalogue No. 150, entitled "Sturtevant Fuel Economizers and Air Heaters", which is dated July, 1911. So far as I know, the statements in this catalogue are true and correct
258 and the figure on page 6 is a fair representation of one type of vertical tube cast iron economizer that was built by my company and in use at that time. It is the staggered type with staggered pipes, natural flow vertical economizer with scrapers. The internal diameter of the vertical economizer tubes was a little less than 4 inches, and the external diameter a little less than 4½ inches. They vary in the molding.

At that time one economizer might serve from one to four or five boilers. We had one in Lawrence, for example, I think, that served 12 boilers. At that time, in 1911, econo-

mizer surface was about 50 percent of boiler surface. That 259
would be about the average.

The gas flow in this economizer figured on page 6 of the catalogue was horizontally, slightly up. The gas tends to rise, of course, and the design is generally to lead the gas into the economizer at about two-thirds of its height, with the idea of keeping it down. It has a tendency to rise, so that all surface would receive sooner or later as nearly as possible an equal amount of gas. Most of the tubes are made from 9 to 12 feet long between headers. That was about the usual practice at that period. I cannot determine that particular installation. I have forgotten just the spacing dimen-
sion. I think about 8 inches one way and 7½ the other. 260

The economizer of the International Paper Company, Rumford Falls, Maine, shown on page 7, was apparently 11 tubes wide, that is, 11 tubes in a section. Apparently there were 36 sections or rows of tubes, but I cannot be sure. The spaces occupied by this economizer would be about 10 feet high, 8 feet wide, and 22 or 24 feet long.

The picture on page 14 of this Sturtevant catalogue No. 150 was the high pressure type, cast iron tubes, a little less than 4 inches.

The staggered relation of the pipes in the economizer as illustrated on page 17 of the catalogue was adopted about
the year 1903, but our company continued to make econo- 261
mizers with tubes spaced in parallel rows and not staggered, both types being manufactured for a period.

The tube scrapers are generally shown on page 6 of the catalogue on the outside of the tubes, some at the top and some at the bottom; they alternate and are on the same chains. The scrapers increase the overall diameter of the tube about half an inch. They are pieces of chilled iron made in three sections surrounding the pipe.

I would not remember whether any induced draft was

262 used for those economizers shown on pages 6 and 7 of the catalogue. At that period, 1911, induced draft was practised by my company on cast iron economizers. The suction at that time varied from practically an inch up to 2 inches, or possibly $\frac{3}{4}$ of an inch up to 2 inches.

[Counsel for plaintiff offers in evidence Sturtevant Catalogue No. 150 as "Plaintiff's Exhibit No. 8".]

In the installation at the Commonwealth Edison Company at Chicago, where I stated the first draft loss was about 3 inches of water, the economizer was of the general type shown on pages 6 and 7 of the catalogue Plaintiff's Exhibit No. 8, but the chamber was restricted so as to increase the
263 velocity. There was a certain amount of gas to pass through the chamber which was restricted to increase the velocity. The diameter of the tubes and the spacing of the tubes were substantially the same as in the exhibit catalogue. The installation of the cast iron economizers by our company for the American Gas & Electric Company was in 1916.

The largest year we had in volume of cast iron economizers was in 1923. These were for installations in power plants. The diameters of the tubes used in 1923 was the same.

Our company first installed economizers embodying the tubes with discs upon them in 1925 at the Nevada Consoli-
264 dated Copper plant in Nevada. The rings had been shrunk on in 1924. I recognize that in power plant installations the space available for the installation of the economizer is often controlling in the type of economizer. I am not familiar with the South Amsterdam plant, and have no knowledge of the facts that existed with reference to that installation.

I cannot tell offhand how many installations of vertical tube cast iron economizers my company made in 1923 in power plants. I think I would find by the records that every one had been in connection with power plants, although there

may have been one or two that were not. I simply know 265
that the volume of business was the largest we ever had in cast iron economizers.

The first steel tube economizer our company built was in 1910. The outside diameter was the same diameter as the cast iron tubes, as we used the same patterns for the headers, that is to say, about 4 inches in diameter. The horizontal tubes of the economizers for the Barrett Company in 1916 were the same.

Our first so-called type X economizer with prime surface steel tube was shipped in 1923, but I cannot tell offhand whether it was horizontal or vertical. I think both types
were shipped, but I cannot be certain. After consultation 266
with Mr. Derry I find that the first horizontal, prime surface, lead coated, steel tube economizer was sold in March, 1923. By prime surface I mean bare surface,—smooth surface.

I cannot give you the names of the companies to whom we sold vertical cast tube economizers in 1923 for power house work, but I can give more recent ones. The plants where these vertical cast iron economizers were used were plants where steam pressure had not been raised to over 300 or 350 pounds. Probably more of them were in the outlying districts of the country where there was plenty of room and
space available, but some were in cities. 267

The tube diameter of the economizer shown in Defendant's Exhibit V is not given but it was a 4-inch pipe. Several of these economizers were built for this company. I would say offhand that we built and installed 20 or 25.

In 1923 I think I told Mr. Derry that space was becoming more important and that he should study the application of extended surfaces for economizers. I do not recall ever seeing in use in a power house a boiler having grilled or ribbed tubes.

268 Of the type X economizers pictured in one section on page 4 of Plaintiff's Exhibit No. 4, our company has sold and installed 30 or 35,—some such number.

The first information I had of the Foster economizer was in February, 1925, at least to know anything about it. The first one I saw was in the following year, February or March, 1926. The Foster economizer shown in the catalogue Defendant's Exhibit A would not be brought to my attention as an officer of the company.

In our type X economizer we connected the tubes to the headers both with the taper metal-to-metal joint and expanded joint. In the Y type they are all expanded. The pipe is
269 expanded its whole circumference against the metal of the header and rolled out with an expanding tool.

Redirect Examination by Mr. HILDRETH.

In our cast iron economizers the length of the tube varied from 4 feet to 12 feet. We have not put in the type Y economizer tubes quite so short and have installed the type Y much longer. Seven feet is the shortest I believe in the type Y.

Recross Examination by Mr. MCKNIGHT.

I am not sure whether the Power Specialty Company and the Sturtevant Company are the only two manufacturers in
270 the United States who are offering to users the extended surface tube economizers. I think they are the only two that have done any considerable business. I have heard rumors in the last year that the Green Company had designed and were installing an extended tube machine just as I had heard rumors of Foster's prior to the time that I saw it. I do not know of any installation that the Green Company has made of this type of economizer now under discussion.

Mr. FREEMAN recalled. 271

Direct Examiner by Mr. HILDRETH.

In defendant's construction at Devon the water flows down and the gas flows up. We have put in more installations where the water flows up and the gas flows down. Also in this Devon installation the water flows in a dual path. This is not the usual arrangement where the water flows downward, which is generally a single path.

[No cross-examination.]

CLARENCE G. SPENCER, a witness called on behalf of the defendant, being duly sworn, testified as follows:

Direct Examination by Mr. HILDRETH. 272

My name is Clarence G. Spencer and my address is 71 Washington Place, New York City. I am forty-six years of age and am vice-president of Baker & Spencer, Inc. of New York. The business of that concern is general engineering and construction which comprises the studying of plant conditions or industrial conditions, designing and recommending and constructing the necessary equipment and buildings.

I graduated from Cornell University in 1904 in Mechanical Engineering. For nine years I was with Westinghouse, Church, Kerr & Company of New York, on general engineering and construction, then I became mechanical engineer for the Toronto Power Company, for about two years, which 273
was an operating public utility in Canada. I then went to South America as resident engineer for the Chile Exploration Company, copper producers, where I stayed for about three years. I then spent two years in the Army after which for three years I was with the American Sugar Refining Company as a member of the consulting board, designing new refineries and the rehabilitation of existing refineries. Then I joined the organization of McClellan & Junkersfeld in New York, Engineers and Constructors, where I was

274 until April, 1927, when I joined with Mr. Baker in Baker & Spencer, Inc.

The nature of my work since my graduation from Cornell has been as follows: I started work on the Long Island City Power House of the Pennsylvania Railroad, my first assignment being in assisting in the erection of Green economizers in that plant, where I wore overalls and started in handling economizer parts. Following that job I was on several intervening operations and then acted as assistant superintendent on the service plant for the Pennsylvania Railroad in connection with the Pennsylvania Station in New York, where we again put in Green economizers.

275 In 1911 I had charge of the design and construction of Blanchard Bros. & Lane leather factory at Newark where I determined the value of an old Green economizer which I removed. I had no economizer contacts with the Toronto Power Company but in South America in 1914 I had to do with my first steel tube economizer. We had 16 horizontal tube economizers made by Babcock & Wilcox, Ltd., of Renfrew, Scotland. With the American Sugar Refining Company I had to do with the selection of economizers for the Baltimore refinery and also the study of economizers in their existing plants, particularly at Philadelphia and Brooklyn.

276 We installed vertical steel tube economizers at Baltimore.

After this I acted as advisory engineer on the major decisions for the Cahokia Station at St. Louis, Missouri. There we provided economizer surface in the form of additional tubes in the boilers, usually referred to as preheater surface. We made a very thorough study of economizers leading up to that decision. That same year I was sponsor engineer for the extension of the Lake Shore Station of the Cleveland Electric Illuminating Company where there had been installed in that plant late in 1921 the first Foster commercial economizer. It was part of my duty to inspect this machine thoroughly and observe its operation. Foster economizers

were installed on the extension to this plant which we de- 277
signated as the 1922 extension.

In 1923 I acted as Consulting Engineer for the Middletown plant of the Metropolitan Edison Company. We installed Foster and Sturtevant type X economizers. Later, while I did not have as close contact with the plant as during its initial design, there was installed a type Y Sturtevant economizer. In 1924 I acted as sponsor engineer on the new Avon station of the Cleveland Electric Illuminating Company where we duplicated the installation at Lake Shore and installed Foster economizers. In 1925 I acted as managing engineer on the Catskill plant of the Acme Cement Corporation where I installed two Sturtevant type Y economizers. 278
By "sponsor" engineer I mean that the man is responsible for that particular job. I think I am familiar with the principles, construction and mode of operation of economizers.

The superheater is an integral part of the boiler in ordinary practice and at the Long Island station of the Pennsylvania Railroad, where I started in 1904, there were 32 boilers each equipped with a Babcock & Wilcox superheater. These superheaters were designed on such knowledge as was available but were too large and it was necessary to reduce the size because the temperature of the steam was excessive.

The fundamental principles of economizer design are that
the economizer must be disposed at the path of the gas flow 279
between the boiler outlet and the stack with the water entering and going through the economizer in the opposite direction to the flow of the gases. The economizer must be designed so as to be readily cleaned, and it must meet the plant conditions for pressures, gas volumes, water volumes and also elevation of water temperature.

I am familiar with the construction referred to in this case as the type Y economizer and I understand the purposes and function of the discs on these economizers is to increase the

280 heating surface exposed to the gases and so to reduce the housing or the space occupied by the economizer. The increase both in the size of the boilers and in their rate of operation has made the reduction of the economizer housing desirable.

Ten or fifteen years ago a boiler of 500 horse power was an average size, and very few larger. That boiler was operated up to 150 percent of rating. That might have been considered good practice ten or fifteen years ago; that is, that boiler operated at that rating would develop 750 boiler horse power. Today boilers of 3,000 horse power are not unusual. These operate up to 300 or 400 percent rating.
281 A 3,000 horse power boiler operating at 300 percent rating develops 9,000 boiler horse power.

In order to establish a basis of comparison on the part of manufacturers and purchasers, it has been the custom of the trade for many years to consider 10 square feet of heating surface exposed to the gas as one boiler horse power builders' rating. This is an arbitrary measurement but at the time that those standards of boiler horse power evaporation and boiler horse power rating were fixed, 10 square feet of heating surface would just about evaporate 34½ pounds of water per hour from and at 212 degrees F., which is the
282 equivalent of 33,500 heat units. Operating a boiler at 200 percent of rating means evaporating twice that amount in the same size boiler. The practice has changed, I might say, in working boilers harder and getting more work out of the same size of boiler, and today in public utilities boilers are quite usually operated during periods of peak at 300 percent of rating, and even much higher. In industrial plants it is not so usual to operate at high ratings, that is, to push the boiler so hard. Utility plants are electric light and power plants whose business it is to make and sell power.

Boilers themselves have been getting larger during the

past ten or fifteen years; where formerly the average was 283
500 horse power ten years ago, today the average is possibly 1,000, and 3,000 horse power is not uncommon. All building costs have gone up since the war, steel, building materials, and labor.

I have had practical experience with the operation of type Y economizers which have been complained of as an infringement in this suit. This was at the Catskill plant of the North American Cement Corporation where the first unit installation was put in service on July 1, 1926. I had one unit open for inspection in the latter part of 1926 and again in March, 1927. I observed the outside of the tubes at the
gas inlet end of the economizer. This was a waste heat in- 284
stallation in a cement plant where the gases are heavily laden with cement dust, in addition to the ash from the pulverized coal used in burning the cement. I found the lead coating to be in good shape. On the second inspection I had tube caps removed for an internal inspection of the tubes and found no evidence of internal corrosion.

I have been familiar with steel tube economizers since 1914 which was in Chile, and since March, 1917, in this country. The economizers of March, 1917, were four inch plain tube economizers mounted above the boiler and assembled from sections of Babcock & Wilcox boilers. The
Babcock & Wilcox sinuous heaters with the tubes slightly 285
inclined from the horizontal were mounted above the boiler with the headers vertical, the gases making three passes across the tubes.

The next type of steel tube economizers I was familiar with was the Sterling integral type built by Babcock & Wilcox and installed in the Baltimore plant of the American Sugar Refining Company. These tubes were in general vertical, bent on either end, and expanded into a large upper and lower

286 drum, the upper drum being an integral part of the boiler circulating system. This was in 1920.

I was familiar with the Babcock & Wilcox steel tube economizers such as shown in the Plaintiff's Exhibit No. 6, which was put in at the plant of the Duratex Company at Newark in 1919.

The liability of steel tube economizers to internal and to external corrosion is a very definite problem. Babcock & Wilcox in their plain steel tube economizers like Plaintiff's Exhibit 6 controlled the internal corrosion by removing the air and dissolved gases from the water before it entered the economizer. External corrosion is controlled by the tem-
287 perature of the incoming water which is kept high enough to avoid condensation of gases and sulphurous acid on the tubes. Internal corrosion has in this manner been eliminated. External corrosion is largely dependent on the amount of sulphur in the coal. In general, these installations have been successful.

The figures showing the extent to which these Babcock & Wilcox steel tube economizers have been installed and used are not published. An engineer can get them only by following the reports in the technical press and the proceedings of technical societies. My opinion is that the Babcock & Wilcox Company are building and installing 50 percent of
288 the steel tube economizers that are going in in the United States today. They predominate in the large utility plants where they are installed in connection with their boilers. The following are a few of these Babcock & Wilcox installations:

Trenton Channel plant of the Detroit Edison Company in connection with 16 boilers. There are 151,872 square feet of economizer surface put in in 1924 and increased successively since then.

Crawford Avenue plant of the Commonwealth Edison Com-

pany in Chicago, in connection with 14 boilers, 154,756 square 289
feet of economizer surface put in in 1924 and added to successively.

Philo plant of the American Gas & Electric Company near Zanesville, Ohio. Initially eight economizers totalling 70,696 square feet, in service in 1924 and since enlarged.

Edgar Station of Edison Electric Illuminating Company of Boston, three economizers totaling 33,273 square feet installed in 1924 and two more added during the present year about equal to original three.

Long Beach plant of Southern California Edison Company, initially four economizers totalling 44,380 square feet, installed in 1924. 290

Columbia station of the Columbia Gas & Electric Company, Cincinnati, Ohio, eight economizers installed totalling 58,400 square feet.

Sioux City plant, three economizers installed, totalling 12,-645 square feet in 1925. Four more units added since.

Twin Branch of Mid-West Utilities at Twin Branch, Ohio, seven economizers installed totalling 61,859 square feet in 1926.

A square foot of economizer surface refers to the area of the surface exposed to the hot gases. Economizers originally installed in the Edgar station of the Boston Edison were
one Foster and, as I recall it, three Babcock & Wilcox. This 291
was in 1924, I believe. The two that have been added this year and are now going into service are Babcock & Wilcox economizers. I have visited this station.

The State Line plant near Chicago, now in the process of construction, with which I am familiar through published reports and discussion with engineers, has a capacity of 204,-000 kilowatts, which is three or four times the size of any unit now in service. Babcock & Wilcox economizers are on order for this station.

292 I am familiar with the economizer of the Kablitz patent, Defendant's Exhibit D, and understand its construction and operation. The function of the discs or flanges on this economizer is to provide more area of tube to the action of the hot gases and to reduce the volume of the economizers. This is not any different in this respect from the defendant's economizer with discs on the tubes. Nor is there any difference in the effect of the discs in the defendant's economizer from those of the economizer of the French patent to Dietrich, Defendant's Exhibit H.

[No cross-examination.]

293 LIONEL S. MARKS, a witness called on behalf of the defendant, having been duly sworn, testified as follows:

Direct Examination by Mr. HILDRETH.

My name is Lionel S. Marks, I reside at Cambridge, Massachusetts, and am fifty-six years of age. I am professor of mechanical engineering at Harvard University, having been connected with the University since 1894, first as an instructor in mechanical engineering and, after a period of years, I became assistant professor, and then professor.

My earliest education was in England. I attended Mason College at the University of Birmingham, and obtained the engineering degree there, then the Bachelor of Science de-
294 gree from London University. I then came to this country to carry out research work at Cornell University and on leaving there was given the degree of Master of Mechanical Engineering.

I am a member of the American Society of Mechanical Engineers, a Fellow of the American Academy of Arts and Sciences, and a few other less important societies.

I have published a considerable number of books, the first a book on Gas and Oil Engines, then a book on the Properties of Steam, then the Mechanical Engineers' Hand Book, of

which I am the editor-in-chief, and for which I have written 295
many sections in addition to supervising all the rest of it. Also a book, The Airplane Engine, and numerous papers before the learned societies and for the technical press. The hand book is called "Marks' Mechanical Engineers' Hand Book". This a standard book, of which nearly 100,000 copies have been sold. I am familiar with literature on economizers and applied apparatus in English as well as in foreign languages.

In all heat transfer apparatus the problem is to take heat from some hotter body and give it to some colder body, or it may be in the reverse direction, from a colder to a hotter. There are ordinarily three resistances to be overcome before 296
the heat can get through from the hotter to the colder body. First of all, there must be some dividing plate or member between the two bodies, one of which is giving up heat and the other receiving it. In the case of an economizer it is a metal tube.

The first resistance, then, is in the passage of heat from the hot body to the metal or other material of the wall that divides the two fluids. The second resistance is to the passage of the heat through the material of this dividing wall; and the third resistance is to the passage of the heat from the dividing wall into the fluid that is receiving the heat. 297
Of these three resistances, in the case of an economizer or superheater, or a boiler, the first is much the greatest. One might perhaps, for an analogy, consider the flow of water through a pipe of a certain diameter, say 4 inches, and there are certain restrictions. In one place it narrows down to half an inch diameter, which we will compare with the resistance to the passage of the heat into the metal of an economizer. There may be another restriction which would be only from 4 inches down to 3½. That would not really act as an important restriction at all on account of the major

298 restriction of the half-inch opening. There might be another restriction further along, and the pipe might be cut down to 2 inches further along. Of those three resistances or obstacles to the flow of the water through the pipe, the only one of real importance is the first one, because that is where your smallest opening is. The same is true in an economizer tube. The heat has got to get into the tube. It has to go from a hot gas, which is a very poor conductor of heat, and the principal difficulty then, in an economizer or a boiler, is in getting the heat from the gas into the metal of the tube or other dividing wall.

299 A comparison of these resistances perhaps might be interesting. Kablitz, for example, whose patent has been referred to in an article that I shall want to exhibit later, written twenty years ago, estimates, and his figures are to my mind substantially correct, that the resistance to the passage of heat into the metal from the hot gases is about fifty times as great as the resistance to the passage from the metal to the water, so that in a heat transfer apparatus such as an economizer, the important thing is to increase the opportunity for the heat to get into the metal.

There are various ways in which one may proceed. The first is the obvious way of extending the surface. That gives,
300 as it were, a bigger opening through which the heat may go in entering into the metal. Another way is to increase the heat transferring power of the gas to such surface as you have got. That you can do by increasing the velocity of the passage of the gas over the surface.

When one analyzes the condition, one finds that close to the metal wall is a layer of gas which is not moving with the main body of the gas. It adheres to the metal and it forms what we shall call a non-conducting layer. Heat that gets through that innermost layer of gas has to go through by

conduction, and since gas is a very poor conductor, the heat 301
transmission is small.

The greater the thickness of that quiescent layer of gas in contact with the metal, the greater will be the difficulty for the passage of heat into the metal. The practical way of reducing the thickness of that layer is by increasing the velocity of the gas. Then the gases moving at high velocity tear away the outermost layer and reduce its effective thickness. Those are the two really important methods of improving the heat transfer from a gas through metal tubes to some other fluid.

Bell's statement in his patent, page 2, line 13, that 302

> "The rate at which a heated gas gives up its heat to a cooler surface, is as well known, almost directly proportional to the velocity of flow of the gas over the surface",

is substantially correct.

There is no fundamental difference at all between an economizer and a superheater from the point of view of heat transference. You have in both cases the three resistances. On the gas side you have identical conditions, except, of course, that the temperatures are not the same because the two pieces of apparatus are located in zones of different temperature. But the transfer of heat from the gas to the metal
is precisely the same in both cases. The transfer of heat 303
through the metal is also precisely the same.

The third transfer of heat, which in the case of an economizer is from metal to water, in the case of a superheater is from metal to steam, and steam which throughout the greater part of this superheater is superheated steam, and therefore is practically a dry gas and has a very low conducting power.

In order to improve the transmission of heat in a superheater which has dry gases on both sides, one has to adopt the second alternative I spoke of for increasing the heat

304 transfer possibilities; that is, to use a comparatively high speed of the superheated steam through the superheater tubes.

A very good example of the use of both methods of increasing heat transfer that I have referred to is given to us by this superheater in which on the outside, where a high velocity of gas is undesirable because of the big draft loss that would have to be made good by a chimney or fan, extended surface is used. On the inside, where it is possible to use high velocities, and a considerable pressure drop is not objectionable at all, high velocity is used. But, fundamentally, the two pieces of apparatus are the same. By
305 using a high velocity of steam in the inside of the tube and thereby increasing its heat absorbing capacities, one approximates fairly closely the conditions of an economizer.

The superheater tube shown in the Foster patent No. 744,-323, Defendant's Exhibit C, fulfils both conditions, namely, the extended surface on the outside and high velocity of steam on the inside, the latter being secured by the device of an internal tube entering the superheater tube proper, the steam returning through an annular space outside the heater tube and, therefore, through a comparatively small cross-section and consequently with comparatively high velocity.

306 With regard to Mr. Reeve's testimony that water or steam will take up or impart heat to the metal very much more rapidly than air or dry gas, I do not agree with this without considerable qualification. If by that he means dry steam or superheated steam, they are in just about the same case so far as heat transfer is concerned as air or gas. As I have stated, by increasing its velocity, using a high velocity, you can increase its power of absorbing heat.

The article to which I have referred on the Kablitz economizer is in a German publication of the date of 1908, the date of the Kablitz patent. This publication is the "Zeit-

schrift des Vereines Deutscher Ingenieure", which means "The Journal of the Union of German Engineers". 307

This article appeared a few months after the date on the Kablitz patent. The date, I think, is May, 1908. This article is dated November 28, 1908, and appears in the journal of the German Engineering Societies, among what might be called perhaps "Notes" in a page which is devoted to notes on things that are of current interest.

In it Kablitz himself describes his economizer and gives more data than is given in the patent. He states, for example, twice that it is a counter-flow arrangement. He says, for instance, I have a translation which I made myself here, 308

> "Through all these tubes, one after another, the water flows in the opposite direction to that of the gas in order to have as great a drop of temperature as possible at all points."

There is a similar passage further on, making it perfectly clear, which is not indicated in the patent, that what he had in mind was counter-flow. He gives here also the dimensions, practically a 4-inch tube, 100 milimeters, practically 4 inches; 6 feet 8 inches long; 4 square meters or 43 square feet of external surface in each of the tubes.

These tubes are arranged vertically in the patent as shown in Exhibit M. He says with reference to that: 309

> "The fear that the external cleansing will be difficult has proved groundless because with gas velocities of about 15 feet per second, no foreign bodies adhere except the soot which sticks like snow flakes to every surface which offers, but it also is blown away at a velocity of 33 feet per second. It is then within our own control to prevent any soot formation worth mentioning, the more so as a velocity of 33 feet per second corre-

310 sponds to a draft loss of only about two-tenths to twenty-eight-hundredths of an inch of water."

Then he goes on further in that same way.

[Counsel for the defendant offers in evidence the Kablitz 1908 article as "Defendant's Exhibit X".]

I am familiar with the German language and read it and have made an accurate translation of this article.

[Counsel for defendant offers in evidence this translation as "Defendant's Exhibit Y".]

I have found another article in the German literature with regard to this Kablitz economizer in the same journal for the year 1912. The article relates to installations of the Kab-
311 litz economizer. The article deals with the activities of a society in Germany for reorganizing boiler houses. It reads to me almost as if this were practically a society in which Kablitz himself was much interested, and as if it were really a society for Kablitz economizers, but it is not so indicated directly.

He gives a description there of a so-called reorganization, the bringing up to date of a boiler house, and describes the new equipment. It is in an armor plate rolling mill apparently of considerable extent. He enumerates all the pieces of apparatus which are installed, but the only one of any real
312 magnitude or importance, apparently is the Koblitz economizer which was installed. He gives the results of continued data, officially observed data, going on for a period of eighteen months or two years on the performance of this plant. He also gives similar data on the performance of an electric power plant in which also these economizers are installed.

[Counsel for defendant offers in evidence the 1912 Kablitz article as "Defendant's Exhibit Z".]

I have had a translation made of this article. I did not have time to make it myself, but went over the translation and it is technically correct.

[Counsel for the defendant offers in evidence the translation of the 1912 Kablitz article as "Defendant's Exhibit AA".] 313

I have read and am familiar with the Bell patent in suit. I think the patent is substantially correct, as a statement of every day practice, where it states that the ratio of economizer heating surface to boiler heating surface has not been greater than the ratio of seven to ten. Of course there are plenty of examples of ratios of economizer surface to boiler surface much exceeding one to one. I could produce for example a ratio of two to one with the economizer surface as much as two times the boiler heating surface. Such cases naturally are not very numerous, but ratios of 314 one to one or larger for economizer to boiler surface are not uncommon, but are not normal.

With regard to the statement of Bell in his patent indicating that a draft loss was some feature of advantage, I should say that a draft loss is an unmitigated evil. I think it is comparable with the taxes which are an unmitigated evil, but you get something in return. Now, whether a draft loss is desirable or not depends on what you are getting in return. You may boast that you belong to a city with a high tax rate, and you may rejoice in it because you are getting great advantages of it,—a very modern, up-to-date city; on 315 the other hand, you may be putting up the same tax in another place, and the local politicians may be absorbing fifty percent or more of it. There is no advantage at all in a high draft loss *per se.* High velocity is an advantage, but you have to pay for high velocity in high draft loss. High velocity is what Bell refers to in the earlier portion of his patent as giving better heat transfer as was commonly known.

I am familar with the defendant's construction complained of as an infringement. The two principal advantages that the defendant secures by the use of discs on the tubes in this

316 structure are compactness and lower costs. The feature of compactness in defendant's economizer and in the Kablitz patent are precisely similar in a general way. That feature of advantage, namely, the increased surface exposed to the gas, is secured in exactly the same way in the Kablitz patent as in the defendant's machine. The same is true with regard to the Dietrich French patent. Those are advantages inherent in the extended surface.

In claim 2 of the Bell patent in suit one of the features is that the tubes are provided with external circumferential extended ribs proportioned and disposed to make the external surface area of the tubes several times greater than its inter-
317 nal surface area. I find this feature in the Kablitz patent, in the Dietrich patent and in the Foster patent No. 1,239,377.

I have made computations to determine the relative ratio of the external surface to the internal surface of the tubes in the several constructions and economizers with extended surface which have been referred to in this case. I have plotted these graphically as being the easiest way in which to grasp their relations. It is necessary to explain the basis on which these calculations were made because there are all kinds of possibilities of misunderstanding. In the matter of the Dietrich French patent, which is on the extreme left in this chart (Defendant's Exhibit BB), the column on the
318 extreme left shown in green, the only information available was the patent drawings. These are of fair size, however, and permit one with careful measurements to get a fairly accurate determination of the ratio of external surface to internal surface. I make that to be 5.8. In the case of the Kablitz, there is a little more uncertainty about the external surface. None of these figures can be taken as rigidly accurate. They are the best approximations that one can make from the data at hand.

In the Kablitz the ratio is practically the same as in Diet-

rich's. It is 5.7. I have shown the Foster and Bell the 319
same, because they are the same construction, and the Foster drawing is far too small to permit an actual determination, but I have made them the same under my understanding, which of course may not be accurate, that what Foster had in mind—I do not know that he ever built his economizer—is what Bell did, and so I have shown those two the same, the figure 6.75 for the ratio.

In the defendant's economizer at the Devon plant the ratio is practically 6. I would call attention to the fact that all of these five are practically the same. There is the possibility of error of a few percent, one way or the other, with
all these quantities, and I should say that it turns out rather 320
curiously that the ratio of external surface to internal surface in these four really separate economizers is practically the same figure,—roughly, about six to one.

In computing and comparing the external tube surface area per unit of space occupied, there is perhaps more uncertainty and there is more necessity for defining exactly what has been done than in the case of the previous ratio. What I have taken here as my unit is each tube, or unit of tubes if they are not exactly similarly placed and each with its own proper spacing, the average spacing that is used in
the economizer. I have not done as one of the witnesses for 321
the plaintiff, I think two of the witnesses for the plaintiff, described that they had done in their calculation. That is to say I have not taken account of the small waste space at the end of the rows of staggered tubes, because that introduces an element which makes your result depend upon the overall dimensions of the economizer.

What I have tried to find out is what may be called the inherent ratio of external surface to volume for the particular type of tube chosen, type of extended surface and par-

322 ticular spacing chosen, eliminating any accidental things such as the effect of staggering.

In the Dietrich patent, the ratio comes out about 13, as shown, and is obtained directly from the drawings, which are good enough to permit a fairly accurate determination.

In the Kablitz, I have taken the over-all dimensions for the unit as shown in his patent, and that includes also space for soot blowers; there is no such space in the Dietrich; but in the Kablitz, there is space for soot blowers.

The Foster and Bell, for the reasons I have already mentioned, I have shown the same. I should perhaps add that in the Foster there is a different arrangement of tubes, but
323 according to the best measurements I could make from the patent drawing, the spacing averaged about the same. It was closer in certain places and wider at others. It showed the average the same, and I have simply put it down as the same.

For the defendant's, I have a different figure from that which was produced yesterday by two of the plaintiff's witnesses. They gave the figure of 10.47 for the ratio. I present the figure 8.45, because there is inherent in the defendant's economizer, and necessary for its successful operation, the use of soot blowers, and it is necessary to have space in which to put them. The compactness, of course, must mean
324 not merely compactness of the tubes but compactness of the structure as a whole; and it happens that in Bell's patent it is proposed to wash the tubes by water and it is not necessary to put in soot blowers, and consequently no space is provided, and that will increase therefore the compactness of the Bell economizer.

In the defendant's economizer, however, on account of the necessity of having such soot blowers, the compactness is reduced, and you will see that it is less than any of the others

that I have calculated; less than Dietrich; less than Kablitz, 325
and less than Foster and Bell.

In defendant's economizer this ratio is shown in red after the soot blower space is included, but if the soot blower space is excluded the ratio is shown by the dotted black pencil addition which is the figure given by plaintiff's witness.

In making these computations the size of the tube is very important but only in connection with the ratio of external surface to volume. For Dietrich I have assumed the same size tube as for the others, including Bell and the defendant's, or practically so, namely $1\frac{7}{8}$ inches inside diameter. For Kablitz I have taken his actual figure which he gives as 100
milometers, or say four inches internal diameter. The actual 326
dimensions for Bell and the defendant are as given by the plaintiff's witnesses and as in the Devon plant. If I had assumed a tube diameter of substantially two inches for the Kablitz patent it would have doubled the ratio and doubled the height of the yellow line in that column.

I am familiar with automobile radiators as they used to be constructed with tubes having discs or flanges upon them. The purpose of these was the same as in this case, for increasing the surface on that side of the heat transfer apparatus on which there was the maximum difficulty for the
passage of the heat, that is on the air side of it. In automo- 327
bile radiators the heat went in the opposite direction from the economizer, but that makes no difference at all to the action. You have got your resistances and resistances are the same whether the heat is going in or coming out. The water was on the inside of the tubes and was the hotter.

In the Keenan and Thomas patent, Defendant's Exhibit G, a superheater is shown in the drawing as placed in the uptake where it is exposed to the products of combustion after they have done all their work in the boiler and are on their way to the stack. This superheater is placed in the same

328 position and shows the waste gases precisely in the same way that the ordinary economizer is placed to operate. One might just as well place an economizer there. The structure shown in this patent would certainly operate as an economizer. It would not be, of course, the best proportions that one could devise for an economizer, but if one took away the steam pipe which is shown coming from the upper portion of the boiler and going to the structure which makes it clear that the thing is a superheater, an engineer on looking at this might very well come to the conclusion that it was an economizer and not a superheater.

[Counsel for defendant offers as evidence Prof. Marks'
329 chart as "Defendant's Exhibit BB".]

When I referred to economizers as large as 200 percent of the boiler I had in mind a plant in Alsace which has a ratio of 2.4. This is described in a book by Donkin and Alexander entitled "Experiments on Steam Boilers" published in 1897. They give the results of a large number of tests and give the data upon plants in various places.

[It is stipulated and agreed that the volumes containing the German Kablitz articles produced by Professor Marks may be withdrawn and photostat copies of the articles substituted in place thereof.]

330 *Cross Examination by* Mr. McKnight.

Referring to Defendant's Exhibit X and particularly the text with reference to the diameter of the tubes shown in Fig. 8, the dimension given refers to internal diameter. The German shows that plainly there is an L with a period after it which indicates the internal diameter, and this means lighter diameter. I do not know of an installation in this country where the ratio of economizer tube heating surface to boiler heating surface is one to one. My reason for stating that in defendant's economizers soot blowers were essential was

primarily from my general knowledge that soot will collect 331
and you have got to get rid of it. It is general experience. Some means is provided I think in all practical economizers for getting rid of soot. Other means than soot blowers may be provided. The plaintiff in its commercial economizers uses something other than soot blowers.

In making my chart entitled "Ratio, External Surface to Volume", Defendant's Exhibit BB, I assumed the internal diameter of the Dietrich tubes as $1\frac{7}{8}$ inches. There is no statement in the text of the Dietrich patent with reference to the diameter of the tubes. In calculating the ratio for the Foster patent No. 1,239,377 for my chart, I assumed the
same tube diameter as in the plaintiff's economizer. I could 332
not get accurate measurements from the patent drawing because it was on a small scale and inconsistent, so I made the assumption that it was substantially the same as in the plaintiff's economizers, taking the figures which were given yesterday by the plaintiff's witnesses for the commercial Foster economizers. I assumed the same tube dimensions in figuring the ratios marked "Bell 1922", for the Bell patent in suit.

Redirect Examination by Mr. HILDRETH.

I have no personal acquaintance at all with the plaintiff's
commercial Foster economizers. The Bell patent indicates 333
water washing. I do not know what is actually being used by the plaintiff.

In the Kablitz economizer the soot naturally would tend to collect on the top of the horizontal discs and in those portions particularly which are not in the flow stream of the gas, away from the gas. In defendant's economizer with upflow of gas the tendency of the soot or dust to collect would be naturally on the direct heating surface, on the smooth surface on top of the tubes.

334

Plaintiff's Rebuttal Proofs.

WYLLYS E. DOWD, Jr., a witness called on behalf of the plaintiff in rebuttal, having been duly sworn, testified as follows:

Direct Examination by Mr. MCKNIGHT.

My name is Wyllys E. Dowd, Jr., and I live at No. 850 Park Avenue, New York. I am forty-nine years of age and am vice president of Foster-Wheeler Corporation, the former name of which was Power Specialty Company. I have charge of the economizer department and design, construction and sales. I have been connected with Power Specialty Company
335 about twenty-one years,—since December, 1906.

In 1900 I graduated from the mechanical engineering course of the Sheffield Scientific School of Yale University. I spent a year and a half in the Chief Engineer's office of the Elevated Railroad of New York, a year and a half at the pipe factory in Paterson, New Jersey, and two years with the Crane Company in Chicago and Bridgeport. Then I went with the Power Specialty Company.

The economizer shown and described in the Bell patent is manufactured and sold by the Power Specialty Company. It is illustrated and described in the bulletin Defendant's
336 Exhibit A, which sets forth clearly the construction. Copies of this bulletin were first distributed to the trade in 1922. On page 2 of this bulletin is an illustration of a model of a Foster economizer which we built in the early period of our manufacture. It was exhibited at the Power Show at the Grand Central Palace, New York City, in December, 1922. That show is held every year at the period of the meetings of the Engineering Society. The show is controlled by manufacturers and runs a week. This model was in existence but was not exhibited before December, 1922.

The economizer illustrated and shown in this bulletin, 337
"Defendant's Exhibit A", is referred to throughout as a Foster economizer. This is because P. W. Foster and E. H. Foster were the founders and chief executives of the Power Specialty Company and prior to the marketing of this economizer the principal product had been the Foster superheater. When the economizer was brought out they decided to call it the Foster economizer. Since that time the Foster air heater, the Foster water walls, and radiant superheaters have all been known as Foster, although the economizer is manufactured under the Bell patent.

The books of the Power Specialty Company show the 338
sums received from the sales of economizers shown in the Bell patent in suit from May 18, 1921 to November 1, 1927, equalling a total of $4,439,270.12. This represents 340 units having a total footage of 1,869,058 square feet; in 1925 the square footage of economizers sold was 386,341, and in 1926 it was 267,106. The net profit for the period specified was $585,411.61.

John Bell is not now living. Prior to his death he was connected with the Power Specialty Company as consulting engineer, from January 1, 1921 to his death in November, 1924. He had been previously connected with the Power Specialty Company in a tri-party contract which involved the 339
Edgemore Iron Works, the Power Specialty Company, and John Bell some three or four years earlier.

Mr. Bell as a consulting engineer received a salary of $10,800 a year. In addition he was to receive 2⅔ percent commission of the price of economizers F. O. B. our shops during his life, and his estate one-half that amount after his death. Prior to his death he had been paid commissions of $34,247.30 and since his death there has been paid and accrued to his estate $46,294.66.

The Power Specialty Company submitted a bid for econ-

340 omizers at the Devon plant of the Connecticut Light & Power Company in the early part of January, 1926. The amount of that bid was $98,720 for four enonomizers, each containing 9072 square feet, delivered and erected.

There had been other instances where the Sturtevant Company has offered extended tube surface economizers in competition with our company. The American Sugar Company in Brooklyn; Wyman Gordon Company of Worcester; Cleveland Municipal plant at Cleveland, Ohio; Western United Gas & Electric Company at Aurora, Illinois. There may be some others. In each instance the Sturtevant Company bid was considerably below ours.

341 In my experience with the Power Specialty Company in selling economizers shown in the Bell patent in suit, in many instances I have succeeded in making a sale because of the representations as to space saved by the installation of such economizers. The engineers of the New York Steam Company were anxious to increase the capacity of their station at Burling Slip and several studies were made, and it was impossible to get a bare tube economizer in the space available to perform the service that an extended surface economizer would. There were four installations made by the New York Edison Company at Hell Gate and in the last installation just closed it was impossible to get an economizer with
342 bare tubes of the capacity desired in the space available.

Prior to February, 1916, the diameter of the discs on extended surface tubes used by our company was 3½ inches external diameter, and the tube surface area per lineal foot was two square feet.

Our company notified the Green Company of the existence of the Bell patent in suit and its threatened infringement thereof. The Green Fuel Economizer Company had bid on a contract and agreed to take it. Some thirty days afterwards the purchaser called me up and asked if my bid still stood and

I received the contract. The Green Company did not go 343
through with their bid and the installation of those economizers, and has never since bid against the Power Specialty Company with respect to the extended surface economizers.

In the book entitled "Generating Stations of the United Electric & Power Company of New York" on page 30 is illustrated a Foster economizer. On page 33 is shown a Sturtevant bare tube economizer, and on page 38 is a Foster economizer. In the text is data as to the capacity of each of those economizers. The square footage of the Foster economizer shown on page 38 is 10,692, and that of the Sturtevant economizer shown on page 33 is 12,110. This economizer has horizontal tubes with smooth outer walls. 344

My information is that the Duratex economizer installed by Babcock & Wilcox Company was put in in the summer of 1920, based on the fact that my drawing was dated January 31, 1920, on which I bid for that job.

[Counsel for plaintiff offers in evidence the book entitled "Generating Stations of the United Electric & Power Company of New York" as "Plaintiff's Exhibit 9".]

Cross Examination by Mr. HILDRETH.

Improvements have been made from time to time in the economizers shown and described in the Bell patent, and manufactured and sold by the plaintiff. We have been trying since 1921 to put out economizers with extended surface 345
in which the aggregate heating surface of the economizers was as large as or greater than the boiler surface, and we have at last succeeded in the last Hell Gate installation. The economizer surface will be 175 percent of the boiler surface. This has been purchased and designed but not yet erected. Up to the present time I think there is a 93 percent economizer at Parrsholes, the Carolina plant of W. S. Barstow Company. Albany was about 100 percent. That was a stand-by station and was not used very much. It is the

346 Municipal Gas Company's plant at Albany. The average ratio of economizer surface to boiler surface in the various installations which our company has made was about 70 to 75 percent as a pure estimate. The installation of the United Paper Board Company at Wabash, Indiana, was very probably 52.5 percent. I do not remember this exact ratio, but I can tell the ratio of the Danville, New York, installation. Our catalogue gives these ratios. The figures are correct.

This 1924 catalogue on page 36 shows the Riverside station of the Municipal Gas Company at Albany, New York, where the ratio of economizer surface to that of boiler was 85.1 percent; that is the correct figure. That is the one I
347 thought was about 100 percent.

I do not remember the ratio of the Knickerbocker Portland Cement installation at Hudson, N. Y. There was such an installation, but in those cement plants the ratio of the economizer surface to boiler surface is very much smaller than it is in central stations. I was referring to central stations when I said 70 to 75 percent. The ratio of the Knickerbocker Portland Cement installation very possibly might be 29.6.

The Alpha Portland Cement Company installation at Martin's Creek, Pennsylvania, was about the same as the other cement plants, about 30 percent. I do not remember the ratio for the United Electric Railway Company of Providence,
348 Rhode Island. That was a very early job. I should agree that it was 59 percent. The ratio of 52.6 percent at the Delray station of the Detroit Edison Company is very probably correct. The Fort Dodge Gas & Electric Company ratio of 46.8 percent I think is correct. Those figures are all in the catalogue.

The model economizer shown on page 2 of the Foster economizer catalogue, Defendant's Exhibit A, had tubes one-half the natural length. I should have to guess as to the length of the tubes; they would be about 6 feet long. The

installation in the catalogue is a photograph. The tubes were 2-inch steel tubes with 4⅝ inch diameter gills, and this was exhibited to show the Foster economizer at the Power Show. 349

The economizer which our company proposed to install at the defendant's plant at Devon had 9,072 square feet. These were to be used with boilers having 16,000 square feet of heating surface and 15,300 square feet. This made the ratio of the economizer surface to boiler surface 54 percent for one and 58½ for the other. We bid on four units of different size; the first was 6,048 square feet; the next 7,560; the third was 9,072, and the fourth was 10,584. Figuring the ratios of these four sizes with each of the two sizes of boiler would give the following ratios: 350

Surface of economizer.	With larger boiler.	With smaller boiler.
10,584	68 %	63½ %
9,072	58 %	53½ %
7,560	48.5%	45 %
6,048	39 %	36 %

When I said that my company lost the contract to the American Sugar Company through the competition of B. F. Sturtevant Company I made a mistake. It was the American Sugar job at Philadelphia. I think it was the Franklin Sugar job at Philadelphia. 351

We bid in competition with Babcock & Wilcox steel tube economizers and lost on this sugar job. I do not know who got it. I did not get the Brooklyn American Sugar Company. The job I referred to that B. F. Sturtevant got was the Franklin job in Philadelphia, not the American Sugar job. I got the sugar companies mixed up.

Babcock & Wilcox Company bid in competition with us for economizers and they often get the jobs. They bid on the plain tube economizer such as been described in this

352 case. As to the proportion or ratio between the square footage of plain tube economizers put in by Babcock & Wilcox in the last two years and the square footage of extended surface economizers put in by my company, our reports of lost business lead me to believe that we are getting about two-thirds of the business. That is not an accurate estimate because there are many contracts that are placed on which we have no opportunity to bid. So it is only guess work, a very vague guess. I can only tell you our lost business account and our contracts received account.

We bid on the second lot of economizers for the higher pressures at the Edgar Station at Boston and lost to the Bab-
353 cock & Wilcox Company. That was the 1,400 pound pressure job. I do not think I bid on the State Line plant. Babcock & Wilcox compete and compete successfully in certain types of installation, but I have a great advantage over the B. & W. Company where space is a consideration.

As to the comparative cost to the customer of our economizer and the Babcock & Wilcox for the same surface, this practically fluctuates all over the map. I think, as a rule, I am a little lower than they are, but I am not sure. I have a much smaller housing, you see, and I do not have the extra weight.

354 The customer who received the bid from the Green Fuel Economizer Company in competition with ours was the Consumers' Power Company, the owning company, and the job was for the Zilwaukee Replacement Company. Zilwaukee is a suburb of Saginaw. That company had a number of old type of cast iron economizers and they were to be replaced by the modern economizers, and bids were received from various contractors, including ourselves and the Green Company. It was a sizable job; there were four units of 10,000 or 12,000 square feet. I notified the Green Company of our patent. I had never seen the drawings of the Green

patent. I only know by hearsay that it was an extended 355
surface economizer. It had been our practice in competitive bids with the B. F. Sturtevant Company to notify the company of our patent when they were offering this extended surface which I thought was an infringement of our patent, and that we proposed to protect our rights.

The figures which I read from Plaintiff's Exhibit No. 9 were taken from the book. I have no personal knowledge as to their accuracy. I do not know who compiled them, only that the book is published by the New York Edison Company.

Redirect Examination by Mr. McKnight.

When, as a manufacturer of economizers, I have up with 356
the purchaser the question of economizer sale to that purchaser, the purchaser specifies the expected performance of the job and the manufacturer has to meet these specifications so that the ratio between the economizer surface and boiler surface is not under the control of the manufacturer at all.

William A. Shoudy, a witness called in rebuttal on behalf of the plaintiff, having been duly sworn, testified as follows:

Direct Examination by Mr. McKnight.

My name is William A. Shoudy, I live in Maplewood, New Jersey, and am 49 years of age. I am advisory engineer to
the General Engineering & Management Corporation, New 357
York City; associate professor of mechanical engineering at Columbia University, and consulting engineer on other work. I am associated with Dr. Charles E. Lucke at Columbia, who is professor of mechanical engineering. I have charge of the instruction in steam engineering practice for the department of mechanical engineering. In connection with my duties I lecture and my lectures include economizers.

I graduated from Stevens Institute of Technology in 1899 with the degree of mechanical engineer, and after two or

358 three years as draftsman, and so forth, I returned to that institution as a member of the faculty, and left there about eight years later, in 1911, as assistant professor of engineering practice. Since then I have been engineer of tests of the Brooklyn Edison Company, Brooklyn, New York; assistant mechanical engineer for the J. G. White Engineering Corporation, New York; power engineer for the American Sugar Refining Company; superintendent of steam stations for the Adirondack Power & Light Corporation of Schenectady, New York; and advisory engineer of the General Engineering & Management Corporation, and associate professor in mechanical engineering.

359 For the Brooklyn Edison Company I had charge of the economy, fuel economy, of the Gold Street and 66th Street power stations. With the J. G. White Engineering Corporation, I designed a number of steam power plants or central stations ranging in size from, I think, the smallest was with a 3,000 kilowatt turbine at Roncevert, West Virginia. The largest included a 60,000 kilowatt turbine at the United States Nitrate plant at Muscle Shoals, Alabama; as power engineer for the American Sugar Refining Company I was responsible for the operation of their power houses. There were six refineries and there was a total of about 60,000 boiler horse power.

360 As superintendent of steam stations for the Adirondack Power & Light Corporation I had charge of design, construction and operation of the Amsterdam Steam Station and the Utica Steam Station, and later, supervision of the Mechanicsville Steam Station. At Amsterdam I added a 15,000 kilowatt turbine and two boilers; then doubled the size of the building and added a 30,000 kilowatt turbine and three boilers. For the General Engineering & Management Corporation, I have designed a 30,000 kilowatt station for New Jersey; a 25,000 kilowatt station in Florida; remodelled the

boiler house at Aurora, Illinois, and some other small, relatively small, jobs in other plants operated by that company. 361

A kilowatt is the method of measuring electric power. It is roughly about one-third larger than a horse power. In other words, a 60,000 kilowatt turbine means 80,000 horse power.

I am a member of the Publications Committee of the American Society of Mechanical Engineers, and a member at large of the Prime Movers' Committee of the National Electric Light Association.

The Prime Movers' Committee is made up of employees of companies operating electric power stations, under the auspices of the National Electric Light Association. The duty of that committee is to report on progress of the 362 development of electric power; that is, the experience of those who have used existing apparatus. The reports are published and are available to the public as a whole, and I believe are considered authentic, possibly the only truly authentic report that comes out regarding central station operation so far as electric power is concerned. This is published serially and each sub-committee offers its report as soon as it is completed.

The term "central station" has been used to describe those power plants of electric lighting and street railway companies which have centralized the generation of power. Years ago we used to have the power plants scattered around the city. 363 Then it was found that one plant could be erected of large size, and that the power could be distributed through the necessary cables; that is where the term "central station" came in. We sometimes speak of a central station; sometimes of a public utility power plant. The industrial plant generally indicates the power plant which furnishes steam or mechanical or electrical power to some industry other than the public utility. The factory power plant, it is sometimes called.

364 The central station is usually very much larger on the average than the factory power plant. It is in the business of making and selling power. Its large size means that the generating units, boilers, turbines, and so forth, are large. Its business is a continuous business. The plant operates 365 days in the year, the company does, at least. The saving of a small percentage of the fuel means a large amount of money per year.

In the factory power plant, some of them run substantially 24 hours a day for 365 days in the year, but generally there is some kind of a let-down. Sundays they are closed, some holidays, and quite frequently two weeks in the year is taken
365 for cleaning and repairs, and so forth. Some factory power plants operate only for about eight to ten hours a day. The consequence is that the factory power plant has a smaller total fuel bill, and one percent of that fuel means less money saved. We find, therefore, that the central station is the leader in the generation of steam power, because the owners can afford to spend a little more money in development. There is no fixed rule about it, but, generally speaking, a varying proportion of steam generated in the boiler plant of a factory is used for some other purpose than generating electricity.

366 My first knowledge of the economizer was what I learned about it in college. It was not widely used; in fact, I believe it was 10 or 12 years after I graduated before I saw an economizer, inasmuch as my work was around near the east. Economizers at that time were cast iron. Cast iron headers and cast iron tubes the tubes in the neighborhood of four inches internal diameter and five or six inches external diameter. They were generally installed with one economizer to several boilers. The gases were led from a boiler to the flue, to the entrance of the economizer, and thence to

the stack. There was almost always provided a by-pass, 367
that is, a system of dampers.

The by-pass means that the system of dampers and additional ducts made it possible to divert the gases from the economizers direct to the stack so that the economizers could be repaired or cleaned. These economizers were naturally large. Quite frequently, and I think generally, the economizers were placed out of the boiler room, because of the large additional cost of building required; sometimes in a separate low building. That condition continued until about 1913 to 1915.

Some time about then there was a slight increase in the
cost of coal. The introduction of stokers had made it possi- 368
ble to get more steam out of a boiler. The temperature of the gases leaving the boiler was higher than formerly; and engineers began to realize that economizers might be used to advantage, whereas previously, except in special cases, there was no wide use. There were some installations made about that time. Boilers began to grow about that time, and attempts were made to install single economizers and a single boiler.

The cast iron economizer was cleaned with a scraper, which was a ring around the cast iron tube. That scraper
was moved alternately upwards and downwards by a me- 369
chanism outside of the economizer proper, and through a rod or chain which passed through the casing. These holes and other holes around the casing and in the flues caused considerable infiltration of air; that is, the air was sucked in by the draft of the chimney, so that a larger volume of gas left the economizer than entered it. That meant a cooling of the gas temperature. It meant a reduction in the rate of transfer. It meant a larger economizer than would have been installed if the casing had been tight. It also meant large induced draft fans, or especially high and large stacks.

370 Between the years 1913 to 1916 or 1917, the economizer was under serious discussion by central station operators. Some were installed, and about that time calculations were made to determine whether economizers justified their existence in a power house. That condition existed until—I do not know just when but about 1919, but I remember particularly the condition, because in 1919 I prepared the proposal of the J. G. White Engineering Corporation for the construction of the Colfax Power House at Pittsburgh, one of the largest of the stations at Pittsburgh.

I made a number of estimates but stated our case on two estimates. One was a plant with economizers, and one was
371 a plant without economizers. In the estimate I included the cost of operation and the cost of fixed charges. I found that there was not enough difference in favor of economizers to justify their installation. J. G. White Company lost that job. It was assigned Dwight P. Robinson & Company. But the plant was built without economizers, justifying my conclusions.

The feeling among central station operators was that whereas they desired to save every pound of coal that was possible, the introduction of an economizer as it existed then meant the use of expensive and large induced draft fans and economizers that were too large for the job because of the
372 low heat transfer. This high cost, together with the cost of the power, offset the fuel saving.

The next step in the development that I recall was in 1920. At that time I was with the American Sugar Refining Company, and we were planning a boiler house in Baltimore, and at the same time a house in Philadelphia. J. G. White & Company were acting as Consulting Engineers on the Philadelphia job. Together with the J. G. White Company, we studied the boiler and economizer situation and decided, and so recommended, to leave out the economizer but to install

a comparatively new type of boiler, the difference being that 373
the tubes were differently arranged so that it was a higher type of boiler run at a low rating.

Our reason for so reporting was that on the basis of the experience of users of economizers there was not enough additional saving to warrant the increased cost, together with another matter which I shall mention in a minute.

Shortly after that the first Hell Gate installation was being considered. The original plan was for boilers and economizers. The Babcock & Wilcox Company offered this type of boiler which I mentioned, and whereas they did not get the order, exactly the same type of boiler was manufactured
and built by the Springfield Company for that job. The rea- 374
son why we did not include economizers was first because we did not believe there was any type of economizer built at that time that would withstand external and internal corrosion except the cast iron economizer.

Hell Gate was the next step that I know of. There were a number of experiments with other materials for economizers, the use of steel tubes for example. Philadelphia took a Babcock & Wilcox boiler without a drum and installed it as an economizer. But the internal corrosion was so rapid that that steel economizer never made any stir in the power generating field. They started with fairly heavy tubes, later
putting in quarter inch walls in order to withstand that corro- 375
sion, and these could not do it.

The next step was the use of the economizer by Mr. Wolf at the Cleveland Illuminating Company, the steel tube economizer. At about the same time, or a few years before that, it was suggested that the corrosion was probably due to the dissolved gases in the boiler feed water, and by boiling this water before it went into this economizer these gases were driven out and internal corrosion was pretty well whipped.

Mr. Wolf put in a Foster economizer about that time.

376 My first knowledge of that was when he described the operation of that economizer in 1922.

External corrosion has caused all economizers some difficulty, not so much with cast iron, but with steel. External corrosion became to be just about as bad as internal corrosion which engineers had pretty well eliminated.

The Philo and Twin Branch stations are operated by the American Gas & Electric Company, who also operate the Stanton plant near Scranton. In the Stanton plant near Scranton, this company has installed a different type of economizer. That is, it is an air to water economizer, and operated in this way: The gases from the boiler pass to an
377 air heater. The air for combustion passes through the air heater, is superheated to a temperature of about 700 or 800 degrees. From the air heater it passes to an economizer. That is, hot air is on one side of the tube and water is on the other side. The water is heated up and the air is cooled. The reason for their use of that type of economizer was that they had had so much trouble with external corrosion on the steel tube economizer, which was a bare tube economizer, and they are experimenting with this other type to see whether they cannot eliminate this external corrosion difficulty.

378 I am familiar with the bare tube, horizontally disposed economizer manufactured by Babcock & Wilcox Company, and also with the same type of economizer manufactured by B. F. Sturtevant Company. So far as my knowledge goes, these two companies are the only ones who manufacture and install economizers consisting of horizontally mounted smooth surface steel tubes.

From my personal experience in the design of power plants, I know of an installation where, because of the requirements as to space available for the economizer, the Foster extended surface tube economizers were specified by

me. That was at Amsterdam, New York. Both the Babcock & Wilcox and the Sturtevant bare surface tube economizers were considered by me for the job, but it was not possible to use either in the space available. I could not get the same external tube surface as could be obtained by the use of the Foster economizer. 379

In the pamphlet entitled "Foster News" of June–July, 1924, is illustrated the plant referred to.

These boilers were to be installed in an extension to a plant in which a great deal of care and money had been spent on the architectural features of the building. It was highly desirable that the general cross-section of the boiler room be the same in the extension as in the original plant. 380 That meant that the height of the roof was fixed. It also meant that the space in back of the boiler was definitely fixed. The plant burns a low grade anthracite. We had developed at that plant a type of furnace necessary for high economy with that type of fuel. This type of furnace is shown on this drawing with a restricted throat, and the gases pass up through the first pass.

It occurred to me that the simplest thing to do was to make this a two-pass boiler instead of a three-pass boiler, for this reason: In the type of furnace we used the space under what is commonly the second and third pass was of no value for any other purpose and I consequently decided to put the 381 economizer in there. The boiler had been raised as high as it was possible. We had designed it to be set as high as possible. We were anxious to obtain the highest possible economy, so that we wanted the largest possible heating surface in that restricted space.

The Foster economizer was the only one that we could get into that space. I tried the Babcock & Wilcox, and I tried the Sturtevant type. The Babcock & Wilcox Company offered us an economizer of 2-inch tubes, straight tubes, but in order

*[Counsel for plaintiff offers in evidence the pamphlet entitled "Foster News" June—July, 1924, as "Plaintiff's Exhibit No. 10".]

382 to get the surface it was necessary to use a tube 22 feet long. The furnace width was 24 feet. There was 10 feet between boilers. It would have been impossible for us to remove a tube 22 feet long because of the restricted space.

In the case of the Sturtevant, in order to get the same space, although a shorter tube had been used it was built out. It was necessary for us to install our induced draft fan at one place, and it was impossible to build a gas duct which would connect the economizer and the fan. There was not room enough to move the fan out.

From my practical knowledge it would not be commercially practical to cast tubes like those shown in the Dietrich
383 patent, Plaintiff's Exhibit L, having an internal diameter of $1\frac{7}{8}$ inches. One or two could be cast but to do it commercially would mean such a large percentage of rejections that it would not pay.

Cross Examination by Mr. HILDRETH.

In the economizer shown on the last page of Plaintiff's Exhibit No. 10, the gases flow downward and the water flow is upward. I have installed Foster economizers in other plants besides this one. There were five in New Jersey of the same general type as that shown, and there were six at Inglis, Florida, and four at Aurora, Illinois. At Whippanny
384 the conditions were almost identical with Amsterdam. The boilers were a little narrower, that was all. The water and gas flow were the same. At both Inglis and Aurora the flow of gas is up and of the water down. The Whippanny and Amsterdam plants burned small size anthracite, generally known as No. 3 Buckwheat. There is no soot produced by the burning of anthracite, substantially none, but there is a finer cinder. The cinder is practically fine coal. We were not at all sure what it would be necessary to do with those two economizers in both installations because we had not yet had experience with that type of economizer and

anthracite flue dust. I am not sure whether we installed 385
water pipes or not in Amsterdam, but I think we did. We also provided for steam soot blowers. I cannot tell you now which the company is using because the plant has not been in regular operation for the past year. It is a hydro-electric reserve. In the Inglis and Whippany installations I believe soot blowers were installed. I think that is also the case at Aurora, but I would have to check that up to be absolutely sure.

I cannot tell you definitely when the Babcock & Wilcox plain tube economizer appeared. I have forgotten the date of the Philadelphia economizer. I have a very distinct re-
membrance of sitting in the office of Dr. Jacobus of the 386
Babcock & Wilcox Company at about the time or during my term of service with the American Sugar Refining Company, which was from 1919 to 1921. He showed me a section of tube taken from the Philadelphia economizer that showed serious internal corrosion and we discussed at that time means of preventing internal corrosion, so that there was the Philadelphia economizer at about that time, but just how long it had been in I could not say definitely.

So far as I know this was the only economizer of that type of Babcock & Wilcox Company, although either in Chicago
or Joliet there was a similar type of economizer used. They 387
also had trouble with internal corrosion. They used a particular grade of paint for protection.

These economizers were not the Duratex. That was about 1920; just exactly when I cannot tell. Mr. B. F. Wood, who was responsible for that job, was a neighbor of mine, and I discussed with him what he had in mind going back and forth on the train. Before Duratex was used he wanted to put in a steel economizer. That was about the same time I was with the Sugar Company. Although Wood was living in the same town I did not know that he was there until two

388 years after I moved to Maplewood, and I moved there in 1917, so it was about 1919 or 1920 that I first heard about that. The Duratex economizer came on to the market to some considerable extent later and it is now a well known economizer.

In all four of the Foster installations that I have spoken of, in order to avoid corrosion we installed de-airaters, which is an apparatus for driving off the dissolved gases. It acted upon the water before it went to the economizer to take out the oxygen and gas.

SIDNEY A. REEVE, a witness called on behalf of the plaintiff in rebuttal, having previously been duly sworn, testified as follows:

389

Direct Examination by Mr. McKNIGHT.

I was in contact with and had personal knowledge of the first introduction of economizers into use in this country. In 1887 I received my second degree in Mechanical Engineering from Yale University. After being instructor for a short time I took a position with Westinghouse, Church, Kerr & Company, a firm of contracting engineers erecting steam power plants. During the first portion of 1889 I was out of the office due to illness. When I returned I learned that the firm had closed an arrangement with Col. Edward Green of
390 England for control of the economizer patents on the Green economizer in this country. This Edward Green, I understand, was the son of the man who had originally introduced the economizer idea in England about the year 1845.

At that time there were no power plants in existence in the modern sense of the term at all. There were no central stations. The electric light was then only about nine or ten years old. The electric street railway was only four years old. There were no electrical power plants that amounted to more than 200 or 300 horse power.

The great power plants of those days were either in Pennsylvania, in the iron and steel industry, or in the New England textile mills. In Pennsylvania coal is cheap, and the production of steam was always a matter quite secondary to the other features of an iron or steel mill. But in New England the great textile mills offered an opportunity for refinements in efficiency and power generation which were not paralleled anywhere else in the country. 391

The load was absolutely steady, hardly varying more than one or two percent all day long. The New England mills had gone into refinements in efficiency such as were visible nowhere else in the land. At that time they were using exclusively large Corliss engines, sometimes compounded, very often condensing, and horizontal return tubular boilers in fairly large quantities. 392

The term automatic as it was used technically by engineers referred to the single valve shaft governor type which came in about the year 1890. But the Corliss compound had been in use since about 1870. The engines which drove the Centennial Exposition in 1876 were great beam type Corliss compound engines.

For these reasons, in the fall of 1889 Westinghouse, Church, Kerr & Company opened a branch office in Boston. I was the only engineer there under Mr. Church, who was directing matters. Our office just consisted beside Mr. Church and myself of one draftsman and one stenographer. 393

The firm of Westinghouse, Church, Kerr & Company was then introducing three novelties into the engineering field, which had a great deal to do with the modification of the type of plant which had hitherto prevailed toward the modern one. The first was the Green economizer. The second was the Roney mechanical stoker, taking the place of the hand-fired flat grate, both of which devices were manufactured by or for Westinghouse, Church, Kerr & Company.

394 The third device was the mechanical draft fan as a substitute for the great chimney. Westinghouse, Church, Kerr & Company never manufactured fans nor, so far as I know, had fans manufactured for them. But they were virtually the initiators of the policy of substituting mechanical draft for the chimney.

In those days every New England town had its great mill chimneys. They varied from 300 to 600 feet high, and were the pride of the town. Those chimneys could produce a draft only if they were kept hot. It was the temperature in the stack which produced the draft. Mr. Church was, I think, the initiator of the doctrine that it would be much
395 more profitable to cool those gases off by additional heating surface and then produce the draft by a fan driven by a steam engine rather than building these great stacks and keeping them hot.

In the prosecution of the idea Westinghouse, Church, Kerr & Company formed a more or less informal alliance with Lockwood, Green & Company, probably the most prominent firm of mill architects and engineers at that time located in Boston. Together they designed a number of mill power plants which included economizers and fan draft. For the fans to produce the draft, the B. F. Sturtevant Company was
396 drawn in. So far as I am aware, that was the beginning of the Sturtevant connection with the draft producing part of our steam generating profession.

I did not have direct contact with that work. I was assigned to the smaller plants. But the fact that we had only one draftsman in the office, often led to my being drawn in to help on the drawings for those plants. In that way, I drew up a number of power plants which included economizers and mechanical draft and, in some cases, stokers. Those plants, while prominent in their character and lead-

ing to later developments which proved important, were 397
comparatively few in number.

The standard plant of the day was a horizontal return tubular boiler with a furnace having a flat grate underneath, fired by hand, and chimney for draft, and no preparation of the feed water other than sometimes what is known as a feed water heater which utilizes exhaust steam for heating the water up to about 200 or 210 degrees F. That was the standard practice. I remember that our pioneer job of overthrowing all tradition and persuading New England mill owners to refrain from indulging in these huge stacks, and also to put in mechanical stokers, was an exceedingly slow
and trying job, although time has since justified it. 398

After seven years of this work and a year in technical engineering journalism, I went to the Worcester Polytechnic Institute as professor of Steam and Hydraulic Engineering. That institute, while a small college, was the first college in the world, and for several years the only college in the world, which grouped its engineering instruction around a practical plant. The center of the institute was a machine shop which turned out commercial product every working day in the year; and the work which the students did in those shops, not only had to pass the inspection of an instructor, but then
also had to pass the inspection of a cold-blooded commercial 399
inspector who would pass nothing that was not fit to go on the open market. It may be of interest to know that these great plunger elevators which drive passenger elevator cars by a plunger, which go down sometimes a couple of hundred feet into the earth, were all developed at that institute. For years they were made only in those shops, and then the business became so great as to be unsuitable for connection with a collegiate institution, and two outside corporations were formed who have since then built those plungers.

My part of the institute included a power house, which

400 had to drive the shop, and in addition had spare engines and boilers for experimental work; and in that boiler house, about the year 1900, I erected a Green economizer built by the B. F. Sturtevant Company, and the next year or so had the pleasure of graduating Mr. Freeman under my tutelage. My department also included a hydraulic power plant of 60 horse power, about five miles north of the city, and it was several years after that plant was in operation that I had the pleasure of conducting the representative of the Cornell University preliminary to Cornell's designing the installation of what is known as the famous Gorge plant at Ithaca, where so much hydraulic engineering has been done since then.

401 After ten years at Worcester, I went to Boston on Professor Marks' invitation and became lecturer in steam engineering during his absence abroad. After leaving Harvard I devoted the bulk of my time to consulting engineering except in the years 1911 and 1912, when I was lecturer at Annapolis, before the Graduate Officers' School at the Naval Academy. My pupils were graduate officers in the Navy, who, after three years of active service, had the privilege of returning to the institute for special work in the Graduate School, so that my pupils ranged about twenty-four to forty years of age.

402 With that exception, I did no educational work after leaving Harvard. My principal work was experting various cases in steam engineering. Primarily the case involving the Curtis steam turbine patents between the General Electric Company against the Cramp Shipbuilding Company. At that time turbines were used in large size primarily in marine work, so that the conflict between the General Electric, which was beginning to work large steam turbines on stationary work, and the Cramp Shipbuilding Company, which was building large turbines for marine work, was a crucial one. I also experted the case of the Terry Steam Turbine

patents in which I think the B. F. Sturtevant Company was 403
defendant, but I have forgotten the pleadings in that.

I also experted the case for the Rateau Steam Regenerator patents which were brought out by Professor Rateau of Paris, which found wide application in American rolling mill work for driving a low pressure turbine from the exhaust steam from the great rolling mill engines, which operated fluctuating loads, as the billet of steel was passed back and forth between the rollers. These were the principal steam engineering cases which would have any bearing upon the matter of the present issue. Professor Marks, in his testimony, was asked to state the general principles underlying the design
and action of an economizer. He described at great length 404
the transmission of heat to the metal and its flow through the metal against resistance; the equalization of temperature in thermo equilibrium; and the transfer then of the heat to the inner fluid on the opposite side of the metal. It was all true, but I want to emphasize that I could state, with equal truth and point and force, that that same process was occurring in every stewpan and tea kettle in the United States that happened to be in use. In other words, he described a physical process which is virtually universal wherever heat transfer occurs, and which has, as I see, no bearing whatever upon the issues in this case.

405

Every steam generating plant today, I am speaking of the larger plants, comprises six great types of heat transfer devices; one is the boiler; the second is the superheater; a third is the economizer; the fourth is the feed heater; the fifth is the air heater, and the sixth is the condenser.

Those six elements are all of them alike in all of these respects referred to by Professor Marks. That is, they all embody heat transfer from gas to metal, through the metal in equalization, and then to the substance on the other side; and yet these six types of element are as different in form as

406 possibly could be imagined. They are alike hardly in any other respect than that they all use tubes, tubes being the best form for getting the surface into some sort of shape where fluids can pass over it.

With the exception of these sweeping statements, there is utter contrast rather than similarity between any two of those elements which carry on our modern heat transfer.

That fact means a great deal. It means that the conditions which have dictated the form and success of each of those elements are altogether different. No sane engineer would ever think of attempting to use a boiler for a condenser, or a condenser for an economizer, or an economizer
407 for a feed heater, or a superheater for any of those things. He not only would be laughed out of the profession, but he would lose all his money. It would be impossible. We have just heard on the record how the B. & W. people, driven by the advancing conditions, the advancing changes and conditions, had tried the experiment of using a drumless boiler for an economizer and had failed; and so far as I know every other attempt to confuse those six different items has failed.

There are two great salient facts in the history of the power generating plant which stand out prominently from this whole record and will be found to be the foundation of
408 understanding of virtually every technical point that arises. One of these facts is that the boiler has come down from all these years from 1887 from my personal knowledge, with no change from the plain tube.

During those years there has been a change from what was known as the fire tube boiler, the horizontal return tube boiler, consisting of a heavy outer shell with the water inside and then flues passing through that water to the water tube type due to advancing pressures and advancing sizes of power. I refer to the water tube boiler which was in existence in 1887, and for about two decades before that. Dur-

ing all that period, from about 1870 to the present day, 409
it has experienced no fundamental change whatever. Of course, there have been many minor improvements in manufacture, but the boiler remains a plain tube affair.

All these years engineers have been familiar with the extended surface tube. Never has it come into boiler practice. Mr. Freeman stated that he had never known of a boiler with an extended tube heating surface. I not only have never seen one but I have never heard of one. I have been familiar with the gilled tubes in other services. We are familiar with them in automobile radiators. We were familiar with them many years before for some other purposes. My chief
contact with them was in connection with ammonia condensers, in which under certain conditions they had a very useful application. In feed heaters for instance, the Wainright people used a corrugated tube, but it was not for getting greater surface. It was for getting expansion. And yet with all this familiarity with the gilled tube, the boiler makers have never adopted a gill tube.

The other salient fact is the persistence of the original Green type of economizer from 1889 certainly down to the present hour. We have been told that in 1903 the old Green plan of setting the tubes in straight rows was bettered
by staggering the tubes so as to break up the flow somewhat. 411
We have been told of bettered means for making the joints and other minor details of that sort, but the fact remains that the cast iron economizer has come down unchanged through all those decades of development.

Now there is a reason for both those facts. I need not at the moment take up what those reasons may have been. The point of importance here is that there is a reason why those forms should have persisted, and I can state from my personal knowledge, because Mr. Westinghouse relied upon me in some respects for inspection of patents in which he

412 might be interested, that all during those years the Patent Office was flooded with applications for elaborate types of boiler, with heating surface elaborated in various forms.

None of them were adopted. They simply did not fit the conditions which dictated boiler design; and it all becomes pertinent here because I wish to point out that the economizer also has its form and design dictated by certain conditions, which did not permit of an offhand choice.

The witnesses for the defendant have described this situation as if the man who wanted to build an economizer had nothing to do but to look at some pictures in the Patent Office and pick out whatever type of tube was suggested to
413 him by those pictures, and put it together, and he had an economizer, which was not true. There were many inventors trying to improve upon the old cast iron economizer, and they all failed.

I have found in a book here entitled "Elements of Heat Power Engineering" by Hirschfeld and Barnard, both of whom were on the Engineering Faculty of Cornell University, a picture of the early cast iron economizer which seems to me particularly useful because all of the different parts are labelled. This volume is of the second edition in 1915, there having been a first edition in 1912. I do not know
414 whether this cut appeared in 1912 or not, but it shows the economizer as I knew it in 1889 with hardly the slightest change. In fact, after search, I cannot detect any item in this 1915 cast iron economizer which varies from the economizer which I knew.

The cut to which I refer is Figure 427 on page 660 of the book; but for convenience I have had prepared some photostats which will be easier to handle. These economizers were built as an addendum to the boiler plant as a whole. The gases which heated them—and I am now referring to the years in which I first came in contact with the econo-

mizer—the gases which heated them came from what was 415
called a battery of boilers, a large number of boilers, some of which would be in use, and others not; but the hot gases from all combined into a single flue and then passed through this economizer in a horizontal direction. The cut shows the gas flow entering at the left and it shows clearly the long vertical cast iron tubes, which were unvaryingly, I think, of a diameter of about four inches inside. It shows the scrapers which were moved up and down the pipes by chains at the top. It shows the reversing gear. In the right-hand figure it shows the reversing gear at the top, which is identical with that which was in use in 1889. It shows the
water inlet at the right-hand bottom of the economizer and 416
the water outlet at the left-hand top. In other words, the flow was against the gas flow. I also found some cuts of the Green economizer published in January, 1909, in the Practical Engineer, of which I have taken photostats.

There is no perceptible difference between the Green economizer of 1909 and the economizer shown by Hirschfeld and Barnard in 1915; and I knew these economizers in 1889, and I think that the record has made it clear that they are still under manufacture and in use.

In connection with that persistence of the old cast iron
economizers, the Dietrich patent was in existence or before 417
the public at least twenty years, during which time it made no impression whatever upon the form of these cast iron economizers.

The Kablitz patent has been before the public fourteen years before 1922, with a commercial Kablitz, as it appears in the record, ten years before the public preceding 1922, without altering the cast iron economizer one iota toward the Bell economizer.

Reviewing a little more in detail the tremendous changes which have occurred in the process of steam generation dur-

418 ing these days of the introduction of the economizer, I have mentioned the old flat grate, the old horizontal boiler and the stack. Since that time, jumping over the interim, the furnace has altered from a matter of a few square feet of flat grate which one man could handle with a poker, until now mechanical stokers handle tons of coal per hour, and develop a fire in a furnace chamber which would make a very comfortable living room in New York City.

The size of the boiler has increased tremendously. In my day the maximum size of boiler built by the Bigelow Company of New Haven, where we usually turned for our boilers, was 125 horse power. Steam pressures had been about 60
419 pounds and were rising then to 80 pounds; and I remember that the Bigelow Company took a decided step in advance when they published their policy to build no boilers which were not strong enough for 80 pounds pressure. It was a great step in advance. One hundred pounds was then unusual, although occasionally you found a plant that had perhaps 120 pounds.

We have been told here that the average power of boiler today is about a thousand horse power, and that the maximum often reaches 3,000 as against the 125 in those early days.

420 Another tremendous alteration has come in in the introduction of the steam turbine, which is capable of construction in units of a size that was undreampt of in the old days of reciprocating engines. There has been mentioned in the record a turbine of 208,000 kilowatts now going into use. That is, 280,000 horse power in a single unit, derived from a single instrument. That is to be compared with the old days when the largest textile mills in New England could boast of perhaps a two thousand horse power Corliss compound condensing engine, and when a 500 horse power engine was a large one.

We have seen the transfer from chimney draft to fan draft, 421
and we have been told how even with fans supplying the draft, whereby the temperature drops out of consideration, the leakage of air into an economizer casing adds to the load upon the fan engine to such an extent that air leakage and erosion have become important factors to be considered.

With those developments between the superheater, the condenser, the feed heater and the economizer all developed into devices unrecognizable in terms to what they were originally—in each of those cases the device which could and did prevail was not at all a matter of either guess work or off-hand selection of pictures. In each one of those devices
inventors were at work by the hundred. Salaried investiga- 422
tors in large concerns were working certainly by the dozen trying at all times to improve these devices; and yet out of it all has come only minor variations to certain stereotyped forms which alone are practical under the conditions.

Mr. Freeman was also asked as to what were the general principles underlying the economizer design, and he replied, "Large heating surface" for one item, a "definite circulation" for a second, and "keeping clean" for the third. That directs us to look a bit into the history of the question of heating surface.

The idea of increasing the heating surface in a boiler and 423
a boiler plant has been one of the most attractive ideas to inventors that we have had. That and the mechanical car coupler, I think, have drawn out more patents than almost any other topics of invention. The idea of these inventors of added heating surface has been universal, I think, that if you could only devise some peculiar form which presented a large amount of surface in some peculiar way, that you would accomplish a great improvement in the art.

None of them have succeeded. The reply of the boiler man to every one of these inventions was, if I want more

424 heating surface I will buy a larger boiler, or I will impose a smaller load upon the boiler which I have; and the boiler man for many years was right. In other words, the question of greater heating surface is not merely a question of something which is always a desideratum. Heating surface costs; it costs in the first construction; it costs in space; it adds radiation and other losses to the boiler plant, and, however you may choose to increase your heating surface, you very soon reach a point where it is no longer best to continue.

That same thing came strongly to the fore in response to the efforts at the introduction of the economizer. The boilerman in a great majority of cases said, we do not want any
425 economizers; if we need more heating surface we will buy larger boilers; and in the old days of low pressures they had a fair amount of argument in their favor.

It was only as pressures rose and the temperatures within the boiler were thereby increased, that the waste of heat to the flue necessarily became so great that the opportunity for economizers increasingly justified their existence.

So we find that the heating surface cannot be referred to abstractly as an advantage which can be referred to, but as a gain only when it is stated in terms of something; and I have noted at least four bases in terms of which the heating
426 surface must be considered in order to determine whether the heating surface is a gain or a detriment.

In the first place we have heating surface in terms of first cost. Cost is an item which is only barely mentioned in this record, and yet it is one of the most cogent determining factors in the design and success of all of these engineering devices.

Any additional heating surface must justify itself in terms of upkeep. It must not introduce into the plant so much interference with operation, or so much labor for cleaning, that it will be a loss rather than a gain; and I have known

personally of many mistakes being made in all of these lines 427
by increasing heat surface beyond the point where it was profitable.

Then heating surface must be profitable in terms of radiation—area. If you increase your heating surface, you increase all your incidental losses, and they soon may get to the point where they no longer pay.

Finally, the heating surface must be profitable in terms of the space taken up. It must be compact; and there we have had a great change in the conditions imposed upon steam generation with the growth of the plant from the old type which I described for 1889.

We all know that with the increasing congestion in cities 428
real estate values are greatly enhanced, so that floor space became an important thing. But quite aside from that, as the boiler plant developed into this great composite thing, consisting of five or six big elements, it was found necessary to build each of these sets of elements in a single unit. That is, the furnace formed the foundation. The boiler was placed over the furnace. The superheater was placed usually over a part of the boiler and underneath another part. The economizer had to be placed usually on the boiler supports, and above that was the fan and the stack.

In the average modern plant the foundation of the stack
instead of being bedded 30 feet in the ground is located per- 429
haps 100 feet above the surface of the ground on steel girders.

So that in the design of a unit composite to that degree, the question of space, and of relative space taken up by the various units, becomes a very important one. We still have plants in which space may be almost disregarded, but there also is an increasing number of plants and particularly the larger plants in which space and compactness has been of prime importance.

If I have kept correct tab on the record the word "com-

430 pactness" has appeared only once in the testimony of defendant's witnesses. As the record stands, it is vague as to the meaning of the word "compactness" in economizer heating surface, or in other words, heating surface in terms of volume of space occupied. It has been assumed that when such prior patents as Dietrich or Kablitz mention an increase in the heating surface that must be synonymous with greater compactness. That is not true. Neither Dietrich nor Kablitz makes any mention of compactness as one of the gains from their structure.

Both Mr. Freeman and Professor Marks were asked as to the general principles underlying economizer design and
431 action. Neither of them mentioned the item of compactness.

I think that those statements are not only true, but pertinent. I think that no one prior to Bell's application in 1922, and none among a great many engineers since then, have appreciated that compactness was a desideratum in economizer design. I do not mean to say by that, that it was not recognized in some degree or other, but I mean in the main the commercial value of compactness was not understood previous to Bell.

I have made up a sheet of figures referring to these questions of heating surface per cubic foot for the purposes of comparison, with a line measuring the figures given so as to
432 appeal to the eye. This sheet states at the top the amount of heating surface per cubic foot visible in the Green cast iron economizer at Matteawan reported in the "Practical Power" for 1909 as 2.60 square feet per cubic foot. Since this sheet was prepared, Mr. Freeman has testified, and figuring from the dimensions which he gave, the square feet of heating surface per cubic foot in the Sturtevant economizer came out to 2.53, a very close check with this figure of 2.60 from the Matteawan economizer of 1909.

That amount I have taken in my graphic exposition as the

unitof comparison, that being the standard type of econo- 433
mizer over some forty years of history, varying hardly perceptibly.

Turning now to the Sturtevant steel plain tube economizer at Middletown, Pennsylvania, I find that the square feet of heating surface per cubic foot is 4.18. The Babcock & Wilcox steel plain tube at Weymouth near Boston, gives 4.21 square feet per cubic foot. Those figures are virtually coincident and I think therefore it is fair to accept those as the best practical attainment by small diameter plain tube economizers.

At the time that Bell applied, these economizers were of
varied resistance. I do not pretend to decide whether they 434
were or not, or whether Bell had knowledge of it or not. That is a question of fact to be decided. But there is fair room for surmise that Bell in his language referring to what was practicable with plain tube economizers was referring rather to the old Green or Sturtevant cast iron plant shown at the top of this sheet, rather than to these later plain tube horizontal small diameter economizers.

Referring to the defendant's plant at Devon, Connecticut, I find 10.47 square feet per cubic foot or more than four times the amount of surface which was attained in the standard cast iron economizer.

435
Computing from the data given by Mr. Keenan as to the standard practice of the Power Specialty Company, and basing my figures upon an economizer nine tubes wide, because that was the width at the Devon plant, I have found that the square feet per cubic foot was 13.84, or more than five times that which was standard for so long with the cast iron economizer.

From the book which has been offered in evidence as Plaintiff's Exhibit 9, I have had prepared photostats of the three pages, namely, 30, 36 and 38, respectively, all appear-

436 ing in parallel upon a single sheet for the sake of comparison by eye as to the comparative volume of space taken up by the Foster economizer and the plain tube economizer respectively.

On page 36 I have added some lines to the printed drawing, which can easily be distinguished from what was printed, in order to make the comparisons fair, taking into account the relative capacity in heating surface. That is to say, if the economizer of page 36 had been made of the same capacity as that of page 30, its width would have been approximately that of the arrow marked "B-30". If, however, its capacity had been made the same as that of the economizer
437 of page 38, then it would have had the width marked by the arrow B-38. A comparison merely by eye, which is all that this sheet invites, shows how much greater space the plain tube economizer must occupy in comparison with the Foster.

The question as to the Dietrich patent is: What is its disclosures in terms of what was known in 1894? Professor Marks has taken the position that Dietrich exhibited a structure which might just as casually have been built of $1\frac{7}{8}$ inch tubes as of any other diameter. To me, that assumption is entirely a gratuitous one, and an unnatural and forced assumption.

438 In the first place, Dietrich shows pipes that are cast. I think we all agree as to that. They are shown as connected by what are known as flange joints to be bolted together. They have to be cast. I agree entirely with Mr. Shoudy that it would be commercially impracticable to cast tubes $1\frac{7}{8}$ inches in diameter and of any length fit for an economizer. It would not be a physical impossibility, but the difficulty in cost from failures would be so great that it would be impracticable. Whether cast with ribs or no ribs, $1\frac{7}{8}$ inches in diameter would not be practicable.

But we have better light even than that as to what Diet-

rich meant in the proportions of his drawings. Dietrich 439
shows his economizer as occupying a flue as was common at the time when he published, and as was particularly common on the continent of Europe, a horizontal underground flue leading from the boilers to the stack.

If we assume a diameter of $1\frac{7}{8}$ inches for the Dietrich tubes, it comes out that the flue of the Dietrich drawing has the capacity of a circular stack $16\frac{3}{4}$ inches in diameter. And according to the formula given in Professor Marks' own "Engineer's Hand Book" that signifies a power capacity for the plant of $37\frac{1}{2}$ horse power. To the engineer the addition of an economizer to a 37 horse power plant is a perfect absurdity. The figures that appear in this record of modern 440
plants have run up into the thousands of horse power for a single boiler.

I, myself, before I heard Professor Marks speak, had concluded that we must attribute a diameter of at least 4 inches to the Dietrich tubes, because 4 inches had been the standard for years previously to Dietrich, and because 4 inches was the smallest diameter in which those pipes could be cast with flanges to be bolted together. When you make flange joints, it must be remembered that there has to be sufficient space to get the bolts in. You not only have to slip the bolts in, but then you have to be able to swing a monkey wrench to tighten them. It would be utterly impossible to 441
build the Dietrich device smaller than four inches and get it together.

Yet even if we grant the diameter of 4 inches, we have, according to Professor Marks' own formula, only 170 horse power, and 170 horse power is absurdly small for an economizer plant. So I myself have figured the Dietrich device as if its tubes were either 4 inches or 6 inches in diameter. With that understanding, it takes on an altogether different significance.

442 The Dietrich patent has been emphasized as showing most thoroughly the idea of a compact economizer with extended surfaces on the tubes and as if that constituted an anticipation of Bell's disclosure in 1922. I cannot see it at all in that light. Dietrich does not disclose any desirability of compactness. He has a drawing which shows a form of flue and a form of economizer space in which space is wasted. That is, aside from the tubes themselves, there is no suggestion of any economy of space. Dietrich did not have at all before him that problem which began to confront the engineers in 1921 or 1922. The demand of the modern highly developed central station power plant boiler has lately been
443 for a compact economizer.

He simply was showing a convenient form of economizer, as he thought, and he recommends it because he says it provides more heating surface. Like all these other inventors he does not say more heating surface in terms of what. If he had done so, he would have brought home to his own mind the fact that the Dietrich economizer, as is a fact, was not an improvement upon the old Green. Its history shows that. It was merely what was then a more expensive form of the old Green. It could not have scrapers, as all economizers had had up to that time, because of the ribs. It was not cheaper to build, because, while we can now build heating
444 surface cheaper with gills or discs than without, that was not true at that time.

And so the history of the Dietrich economizer proved exactly what I think the face of the paper shows, and that is that it was a suggestion for a modification of the old Green economizer which was not an improvement at all, but was a step backwards. It not only did not lead to any further use of Dietrich economizers, but it did not lead a step toward the Bell disc tube economizer of twenty-eight years later.

Turning now to the Kablitz economizer, and referringfirst

to the 1912 article, because on page 1742 there appears an 445
assembled drawing of the plant in which Kablitz erected his economizer, and which gives us an excellant idea of the task which he had in mind. Here is a large plant of horizontal shell boilers, ten of them, leading into one of these large horizontal underground flues which were common in Continental practice. This flue leads off to a vertical stack at the right hand of the figure. In a small portion of that huge flue Kablitz has erected, or more properly has suspended, a series of economizer tubes. There is no faintest suggestion in the entire plant of any economy of space. The flue is enormous. There is apparently some 15 or 20 feet of space
between the boiler house and the stack which was needlessly 446
there. That is, needlessly from the American point of view. The whole thing is wanton in its consumption of space.

Kablitz himself makes no mention of compactness as a recommendation for his structure. He merely points out that it does save some waste heat and that it is not the objectionable feature which economizers were then commonly regarded, because, as he urged at two different places, any tube which breaks down can be removed during the noon hour without interfering with the operation of the boilers.

He does speak of his discs on his tubes as increasing the
heating surface. That was obvious. All engineers knew 447
that heating surface could be increased by placing discs on pipes. But he does not mention any reason for that. He does not say in what terms they would constitute a gain. He does not say whether they will save space or save materials. In other words, Kablitz was not at all in competition with the smooth tube economizer, nor was he meeting users whose objection to economizers was that they did not have room for them. He was appealing to a public where the engineer of the big plants did not believe in economizers at all. The engineers did not believe that they would win

448 enough heat to pay for the interference with operation which was due to broken pipes and all that.

As to the question of draft obstruction which enters into the topic of compactness, I need to correct Professor Marks' testimony on that point. Professor Marks mentioned on page 104 of the record that Kablitz's draft was two-tenths to twenty-eight hundredths of an inch of water. Professor Marks at that time was referring to the 1908 article, and the 1908 article makes no mention whatever of draft.

The 1912 article does make a statement as to the draft, stating that it is four to five millimeters. Four to five millimeters are not equivalent to two-tenths or twenty-eight hun-
449 dredths. Their equivalent in inches is .157 for the smaller figure or .197 for the higher figure. That is to say, Kablitz's draft resistance was to vary from a little over one-seventh of an inch to a little less than one-fifth of an inch, the average of which figure is about one-sixth of an inch. Compare that with the statement in the Bell patent that he proposes to use 3, 4 or 5 inches. That is at page 6, line 45. We see what a tremendous contrast there was between Kablitz and Bell.

Kablitz was in the attitude, which was stereotyped throughout all those forty years, of apologizing for his economizer and insisting that it took very little draft indeed, because all the engineers had at their disposal merely a fixed amount of
450 draft, and if they installed economizers the boilers got that much less draft, because of the interference of the economizer, and so the problem always was: Can the economizer save as much as it costs in draft? Kablitz shows his recognition of that fact, and his argument is that his economizer does save as much as it costs in draft because it costs very little draft.

That is the direct opposite to Bell's whole position. Bell says, "Build your economizer so that your draft resistance deliberately goes up to 3, 4, or 5 inches", which is from 20

to 30 times Kablitz's draft. Then Bell explains, "If you do 451
this in the certain way which I have advised, you will find it profitable." That was rank heresy according to all standard engineering thought up to that time. We have before us hardly a statement more pertinent of that standard position than this very Kablitz disclosure.

I have here a drawing which I had prepared in replica, enlarged, of Fig. 5 of the Kablitz patent. After the drawing had been completed and photographed, I discovered that the draftsman had drawn in this frame of a double rectangle which appears in Fig. 3 of the Kablitz patent, but does not appear in Fig. 5. The difference is purely technical, and
does not affect what we have to say, but I should call atten- 452
tion to the fact that the diagram is correct according to Fig. 5 only when we refer to the matter inside of the rectangular lines.

In my diagram, I have drawn in in full lines what is shown in the patent drawing in dotted lines, because what we wish to know about in the present contingency is obscurely shown in the patent drawing by these dotted lines. Thus we get a map so to speak of the horizontal appearance of the Kablitz patent. The tubes, as they are suspended, are arranged in the form of a chess-board. It is just as if we had a chess-board and located a flue on every black square, and left the
space corresponding to the white squares vacant. 453

In other words, Kablitz has made no slightest effort to occupy more than half of his available space with tubes. It is true that he has arranged his rows in such an alternate way that the current of gas passing between one pair of tubes finds a single tube in its way, and therefore has to split. But that is not what is known as staggering in the engineering art as a means to compactness because Kablitz says he deliberately arranged his tubes in the first row so that the currents of gas which escape tubes are very wide.

454 There is a great waste space in between each pair of tubes which is equal to the space occupied by the tube itself.

In other words, there is nothing about the Kablitz patent either in the drawings or in the text which indicates or discloses at all the idea of the commercial value of compactness. There is none showing any valuation of compactness in terms of space to be saved. There is none revealing any valuation for compactness as a means for developing profitable draft friction. It is simply, as I see, a device for which he somewhat apologizes, to be dropped into a plant in such a way that it would not much interfere with the operation of that
455 plant, and yet would present some gain.

Referring next to the Foster patents for superheater and economizer respectively, I would say in order to save time that practically these same remarks apply to all of these disclosures. They are not disclosures of compactness. They are not disclosures of the value of compactness. The most striking instance to me of the inventiveness which was required in order to produce the Bell invention lies in this very fact that none of these very men, Bell and Foster and Keenan, who were in daily contact with the Foster superheater tube on the one hand, and with the economizer problem on the other, until Bell finally did it in 1922, saw this secret of the value of compactness on which Bell bases his invention.
456 I am now referring to the Foster patent 1,239,377, Defendant's Exhibit F.

In the Keenan and Thomas patent 1,282,851, Defendant's Exhibit G, we find a device for the superheater for marine boilers which apparently uses the Bell idea. That is to say, it uses horizontal tubes having discs, and it disposes those tubes in a staggered fashion.

The first thing to be noted about this Keenan-Thomas patent is that it is applied to a marine boiler. If there is any fact which is axiomatic to the engineer it is that the practice

which is valuable in marine work is not necessarily valuable 457
in stationary work; or conversely, that practice which is good in stationary work is not necessarily good in locomotive or marine work. In other words, the arts are not all interchangeable, nor can we argue from one art to the other as to feasibiltiy or value.

Then again, Keenan and Thomas were dealing with superheaters. They virtually have disclosed merely a Foster superheater applied to a marine boiler. The Foster superheater with its disc tube was admittedly common and familiar to all concerned for many years before Bell made his invention. Nevertheless, the fact that those superheaters were used on stationary boilers and here as shown as applied to marine 458
boilers, did not argue at all their value for economizers in in another art.

This patent therefore stands to me in parallel with the Kablitz patent as being an excellent exhibit of how near in the superficial sense men might be led by accident into approaching the Bell structure, yet without getting there and without seeing that that was the road to a profitable end. All this will become more plain when we compare it with what Bell actually did when the time came.

The square feet of heating surface per cubic foot of space occupied in the case of the Dietrich patent is, if we assume the tubes to be 4 inches in diameter inside, 4.85 square feet 459
per cubic foot. If we assume that the diameter of the tubes is 6 inches, which would correspond to a boiler capacity for the plant of about 370 horse power, then the square feet per cubic foot falls to 3.23.

In the case of the Kablitz patent, the square feet of heating surface per cubic foot runs to about 7½. In other words, the rise from the figures for the plain tube economizers of about 4.2 which are already in the record, was raised by Kablitz to about 7.5 by the use of his discs, but whether it is

460 an advantage or disadvantage does not appear in any other respect than that Kablitz's commercial success has been confined to Germany, with no appearance of it in this country, and so far as I am aware none even in England. In making my computations with respect to heating surface per unit of volume occupied, I have taken into consideration the tube bank itself only. In the case of the staggered banks, I have taken in the waste space at each end of the row which Professor Marks thought was not necessary, but as that is conservative from our point of view I have done so. In the case of Dietrich there is no such allowance. In the case of Kablitz the only data on which we could proceed
461 were the measurements of the flue space, the over-all space, covered with Kablitz's own statement of the amount of heating surface per tube.

It is beyond dispute that Bell gave clear instructions in the first place as to the use of ribbed tubes. Secondly, as to their horizontal disposition; thirdly, as to their location as closely to each other as Bell deems practicable, namely, with a spacing between centers of about 1¼ times the diameter of the discs; and fourthly, that this shall be done with the deliberate purpose of incurring a draft loss very much higher than had been previously deemed advisable.

462 It has been alleged against the Bell patent that it is vague. In respect to these items just mentioned there is no approach to vagueness. Bell was directing the engineering profession to proceed in a direction exactly opposite from that which had been the standard. He was stating that the profession should deliberately start to increase the draft resistance, but that it should do so by making its heating surface as compact as possible. These are instructions in the nature of a direction of procedure, and it was a direction of procedure which did not vary from previous standards by some oblique

angle or direction. It was a right-about-face. It was absolute news to the engineering profession. 463

It is true that the engineering profession previously, when they had built an economizer, had been disposing the tubes as nearly together as might be convenient, simply for the sake of avoiding sheer waste of metal. But that does not mean that they were disposing them as closely together as they could in order to obstruct the draft. The whole idea was the exact opposite. Every disclosure which we have had before us in this record, if it mentioned draft at all, has mentioned very small draft, and a draft which was apologized for. Bell was the first to tell men that they should go in directly the opposite direction. 464

Professor Marks regards the draft loss as an unmitigated nuisance or waste, and so it might be if we simply incurred the high draft loss with no intelligent correlation of parts so that that draft loss might be effective. But Bell says to make your heating surface as compact as possible, with horizontal staggered tubes so that your draft loss when incurred shall mean that you have brought your gases into a correspondingly closer contact with your heating surface, whereby you get results which pay and more than pay for your higher draft loss. That was all specific, all definite, and it was in exactly the opposite direction from any previous disclosure that we have before us, and so far as I know from any previous engineering practice. 465

Then again, the testimony of Mr. Dowd showed how very proper were those instructions. While it was recognized that the builders of the Foster economizer did not have under their control the selection of the amount of heating surface, and probably also of draft loss which was to be involved, yet they were continually urging that the heating surface should be more and more, and the draft loss more and more, and the proof of the years has been that, as time has elapsed and

466 experience has accumulated, the users of the economizers have seen the wisdom of that procedure. And so we find that whereas the earlier installations ran, we will say, around 50 percent of boiler heating surface for the economizer, they are now approaching 175 percent, and the draft losses are going up, I understand, correspondingly, though I believe that has not figured so exactly in the record.

Professor Marks used the simile of the civic tax as describing the economizer draft loss. That simile seems to me an exceedingly happy one. It is not only happy for his purposes but it is happy for mine, because if we carry out that simile into civic fields we find that there is a very great dif-
467 ference of opinion among those who are interested in public questions as to whether a tax is an unmitigated waste or not.

I am not going to debate for a moment here, of course, which party to the tax question is wise or unwise, but it is pertinent to point out that although we live in an age which is up to the present time demanding in majority opinion the reduction of taxes, there is also a very large and intelligent minority of people who believe the exact opposite.

In other words, Professor Marks' tax simile expresses exactly the opinion of the engineering world in regard to economizer draft losses up to the time that Bell taught them
468 better. They had regarded these draft losses as an unmitigated waste, for which they might or might not get some incidental and adequate return. But if we come back to our civic taxes, we find that there is a large part of public opinion which preaches literally that higher taxes should be incurred, just as Bell teaches that higher draft losses should be incurred.

This minority points to the fact that not only have taxes risen steadily with the years and with a gain in quality in civilization, but that taxes are expended through channels

which are actually much more efficient than the money 469
which is expended through commercial channels.

I myself can qualify to speak on this, because seven years ago I published a large 900-page economic history of America under Dutton & Company. In that I pointed out that the efficiency with which we spend our money through ordinary commercial channels was about 70 percent only in 1850, and about 30 percent only in 1900, and about 20 percent in 1910 or 1915, and is now probably about 18 percent; whereas even under the most corrupt government our civic taxes are expended with an efficiency probably not less than 50 percent
or 75 percent. 470

I merely want to show that these things are not obvious, that whether a thing is an unmitigated waste or not is not an obvious question, and that there may be a very large or preponderating public opinion which regards such a thing as economizer draft loss as an unmitigated waste, when as a matter of fact it is not what may be made supposition of an unmitigated waste.

That is exactly the situation with the changing mechanical conditions—the draft loss in the enconomizer was ceasing gradually to be a loss, and was becoming a potential source of profit. It was not an actual source of profit until Bell had
brought out the new structure, the new policy of construc- 471
tion, whereby the loss might be made a gain; and so we find the old type of economizer still persisting.

But here was this increasing and influential minority of large power stations under the conditions of which a very high draft loss might be made an actual profitable gain. Not only that, but a gain so great that it paid to put into that draft loss an amount of heating surface equal to, if not greater than, that in the boiler itself.

Now we could not have a better simile of the very mental discretion which we wish to bring out, between Bell in his

472 advocacy of an entirely new line of equalizer [economizer] construction and the prior art which was either content with the old device, the smooth cast iron economizer, or if it went after compactness at all, went after it in a half-hearted and unprofitable manner.

I say we could not have a better exposition of the contrast between that attitude of mind and Bell's attitude of mind, which was to the effect—discard entirely your old standards of construction; not only adopt the gill tube as a well-known expedient for extended heating surface, to make that heating surface so compact that it shall actually develop a high draft resistance, and then when you have carried that out in a sub-
473 stantial way you will have gained.

Now, when we turn to the language of claim 2, which I need not quote in full, I hardly think I need to quote its elements again. It is merely necessary at this point to call attention to the fact that the combination of claim 2 does not appear in any prior disclosure which has been brought into this record. There has been no disclosure entered whatever which combines the horizontal gill tubes, closely spaced and staggered in such a way as to develop compactness and draft resistance, as the primary aims in design, with the other incidents to the claim as they may appear.

474 We have before us merely a series of disclosures which might be argued, by a stretch of the imagination, to be aggregable into something like Bell, but in each case we not only have to bring together elements which are, according to the analysis which I have already given, incompatible and which have not been associated in the past, but we have to bring together those elements distorted. There is not a disclosure before us which would make a good modern economizer, unless it were deliberately distorted in large degree.

I have brought out how Professor Marks had to distort the Dietrich, in order to make it even superfically like a modern

economizer, and that this distortion has been proven by the given engineering testimony to have been impractical. My point is not merely that it was impractical, but it was vain, and even if we distort Dietrich to the extent that Professor Marks stated, we would not then have a useful modern economizer. We would not even have an economizer better than the old cast iron economizer. 475

The same thing is true of Kablitz, that we could not make a Kablitz economizer which would be of any use whatsoever in a modern central station power plant unless we distorted the disclosure of the patent, and the commercial article beyond any scope of the patent. 476

With respect to the directions given by Bell in his specification for the spacing of tubes, this is set forth in the Bell patent in suit on page 2, lines 67 to 76. See also page 2, lines 55 to 63.

The spacing in the Devon plant and the spacing in the Foster commercial economizer is such that the average distance between tube centers is, for example, in the neighborhood of one and one-quarter times the maximum tube diameter. That proportion is closely observed.

[Counsel for plaintiff offers in evidence the following:

"Elements of Heat and Power Engineering" by Hirschfield and Barnard, as "Plaintiff's Exhibit No. 11", and it is stipulated that the book may be withdrawn and a photostat copy of Fig. 427, Economizer, be substituted. 477

An article from "Practical Engineer", dated January 1, 1909, entitled "Green Fuel Economizer", as "Plaintiff's Exhibit No. 12, and it is stipulated that a photostat copy of said article may be substituted.

Photostat copies of pages 30, 36 and 38 of defendant's Exhibit No. 9, as Plaintiff's Exhibit No. 13.

A drawing produced by Prof. Reeve of Fig. 5 of Kablitz patent, as "Plaintiff's Exhibit No. 14."

478 A sheet produced by Prof. Reeve entitled "Comparative Heating Surface per Unit of Volume, as "Plaintiff's Exhibit No. 15".]

Cross Examination by Mr. HILDRETH.

The method of heat transfer was the same with the ordinary stew pan and tea kettle as with the economizer or superheater. No portion of the economizer is exposed to radiant heat. The ordinary tea kettle upon the stove with the cover lifted may or may not be exposed to such radiant heat. If it is placed upon the stove with a cover on it, it makes direct contact and receives heat by conduction. The pro-
479 cess is the same. There is the transfer of heat from gas to the metal, which is the same in all forms of transfer. There are differences due to the kettle exposed to the open flame and the radiant flame which would be comparable to the boiler fuel and the method of heat acceptance, but a tea kettle over a blue flame and over a non-radiant heat flame would be getting its heat exactly as the economizer does, merely from the hot gases. We virtually have no tea kettles over radiant flames any more.

A feed water heater is a device involving tubular heating surface in an enclosed shell, in one portion of which various waste steam is conducted from steam pumps, or in modern
480 large plants commonly by bleeders from various stages in the steam turbine, and through the other portion of which the feed water is conducted so that the feed water is heated up to temperature only of 200 degrees or more before it enters the economizer.

The exhaust steam is very wet, so in that case you have very wet steam on one side and water on the other and it is practically a question of transfer of heat from water to water through a metal wall. But in the transfer to the surface of the metal and then through the metal, and through the metal

again to the water, we have the same series of steps that was 481
described by Professor Marks.

A condenser is a similar device made up with a large amount of surface in tubular form inside of the shell into which the exhaust steam from the turbine or reciprocating engine is led, and through the tubes of which cold water is circulated, whereby the steam is condensed. Here again you are working with very wet steam and you have practically water on both sides of the metal tube, so that the problem of transferring the great amount of heat from the gas on one side to the metal of the tube is not present at all in either of those constructions.

In Plaintiff's Exhibit No. 9, page 32, in the upper right- 482
hand figure of the drawing shown on that page is illustrated the water wall tubes. They are placed on the side walls of the furnace of a steam generating plant as shown on page 33 of this book. They form a portion of the boiler and take an important part in the generation of steam in the boiler. They have longitudinal fins along each side parallel to the axis of the tubes. They do not constitute the extended surface in the sense in which that term has been used here. They are not for the same purpose at all as the discs in any of the disc tubes which have been under consideration in this case. In the first place these water wall tubes are 483
arranged necessarily so that only one-half of their surface receives heat. The other half is embedded in the fire brick. Such a construction as that could not be designed for multiplying the heating surface in the sense in which the disc tube is used in the place of a plain tube. There is a case where the tubular surface is used for the internal strength against the fluids, and secondly, the wings are there largely for the protection of the brick. They do absorb the heat, but their form and function is altogether different from the transverse discs. The wings absorb heat and transmit it through the metals to

484 the water inside of these tubes and the fin on one side increases in that respect the heating surface exposed to the heat in the furnace. I never did any engineering in connection with a plant having these Murray fin tubes, as they are called.

I was familiar with the Stirling boiler of twenty years ago, but I do not know what it is today. In the time of my acquaintance with them they had never built an economizer in connection with their boiler. I began to dissolve my active connection with steam engineering work fifteen years ago. That does not mean that I have had nothing to do with it since.

485 Referring to the circular of Bigelow Company and particularly to the boiler illustrated on the front page, the right-hand element there shown is an economizer. The feed water enters at the bottom and flows over toward the boiler. The upper drum of that economizer is connected directly to the steam drum. In other words, that is merely a section of the boiler. It may or may not make steam, but it is a section of the boiler. Whatever steam it makes goes over into the main header, or if it fails to make steam, the steam from the main header flows over into it. The feed water goes to that section.

486 The drawing on the inside left-hand page of this circular shows in the extreme right-hand section a drum and parts which appear to be built to act as a small economizer. The amount of the tube surface is about 20 percent of the total tube surface and there is a short direct connection between the upper drum on what has been called the economizer and the steam drums of the rest of the boiler. In other words, it is a compromise measure performing some of the functions of an economizer. The function of the economizer is to heat the water in such a way that there can be no travel back of the steam from the boiler proper to the economizer. Bell, of course, in his patent has a great deal to say about that. It

was not emphasized in this suit, because the particular claim 487
which was in suit did not refer to that matter; but that is the whole function of an economizer, to reserve itself to the function of heating feed as contrasted with making steam, and in order to do that it must be protected or must protect itself against steam temperatures. That is not true of this so-called economizer in the Bigelow book. The lower part of that bunch of tubes would necessarily be filled with water colder than boiler temperature, and that portion would act as an economizer; but there is nothing demarking that function from the function of the boiler proper.

The lower part will act as an economizer, and the steam
is generated in the upper part. That will act as a part of 488
the boiler, and even if it failed to impart enough heat to bring the water to steam temperature, the structure itself will lead back enough steam to bring the top of the so-called economizer to boiler temperature. This is an invasion of the essential function of an economizer.

I do not know the size of the connections, but it would depend upon the size of the connections upon the rate of feed flow. The boiler might be forced so hard that it might all of it act as an economizer, but there is nothing in the structure to make it essentially an economizer.

[Counsel for defendant offers in evidence the circular
of the Bigelow Company as "Defendant's Exhibit CC."] 489

The condenser of a house turbine, that is, one of the turbines used for generating auxiliary power in the plant, may be a feed water heater. I do not know the modern practice in this respect. The same piece of apparatus may act as a condenser and a feed water heater. To act as a feed water heater there can be no such thing as a vacuum. You have not got a true condenser in the normal sense of the term at all; you have got a high-pressure condenser. The steam would be too cold to heat to any temperature below 212 de-

490 grees F. and still have a vacuum. The ordinary turbine condenser exhaust has a temperature of not much above 100 degrees F. You can heat water to 200 degrees or more with steam at 100 degrees.

In making my chart, Plaintiff's Exhibit 15, the figure of 10.47 for the Sturtevant gilled tube, Devon, Connecticut, as it is marked on the chart, was determined in the manner explained in my testimony on the prima facie case.

As to the proper way of figuring the surface area per cubic foot of space occupied, while Professor Marks omitted these half spaces at the end of the rows of staggered tubes, I included them because I thought there might be a question as
491 to that, and because it was against us to include them. This is not enough to account for the difference between my figures and these of Professor Marks, which were 8.3. I did not take into account the space occupied by the soot blowers in the defendant's apparatus. These soot blowers are deemed necessary by the defendant, but they are not necessarily the only means of cleaning the tubes. The defendant has elected to set aside certain spaces for soot blowers as a substitute for the Bell patent method of washing from above. It did not seem to me that those were an essential feature of the economizer proper. The patent states that compactness of the heating surface per cubic foot shall refer to the bank of
492 tubes, and the soot blowers in the space allotted to them are not a part of the bank of tubes. They occupy the space which the tubes do not occupy.

The economizer first appeared in England, I understand. I cannot speak exactly as to whether the greatest economizer development is there or not. They certainly have not had any development, or any reason for the development, of the central station along American lines, or to American degrees, simply because they have not carried the distribution of electric power from the point that we have, nor do they

suffer from congestion in the degree that we have. I have 493
never made any study of foreign development of the economizer or visited foreign countries to see what economizers were in use.

I cannot mention a chimney or stack in New England 600 feet in height. I think that may have been an exaggeration. I cannot now remember one 300 feet high, but I know that years ago I remember distinctly that they ran up into 400 feet in some instances, particularly foreign stacks.

I was in error in stating that the Kablitz 1908 article, Defendant's Exhibits X and Y, did not make any mention of draft loss. It does show and states a higher draft loss than
the 1912 article which I quoted. The draft loss given in this 494
1908 article is 5 to 7 millimeters, which is .275 inches.

In the drawing which I produced of this Kablitz patent, marked "Plaintiff's Exhibit No. 14", I did not show the discs or flanges. Defendant's Exhibit M, drawing of Kablitz economizer, transverse section, correctly represents the tubes and flanges as they would appear if the Kablitz economizer was cut by a horizontal plane.

Bell states in his patent in suit, page 5, beginning on line 74, that he prefers to space the centers of adjacent tubes apart about $1\frac{1}{4}$ times the maximum tube diameter. Figuring
the same proportionate distance between adjacent tubes in 495
the Kablitz economizer as shown in the drawing Defendant's Exhibit M, I find the diameter of the disc is about 2.12 inches. The distance of separation between the tubes in one direction is 3.28 and in the other 2.31. This gives a ratio of 1.55 for the major, and 1.09 for the minor or diagonal distance between adjacent tubes.

I find no mention in the Dietrich patent of any particular dimension of the tubes, and the tubes and other parts in the Kablitz patent are taken from the Kablitz article. The ratio of $7\frac{1}{2}$ square feet per cubic foot of space occupied for the

496 Kablitz economizer was figured from the dimensions given in the Kablitz article. This article gives in some respects the dimensions of the economizer itself, and in other respects the dimensions of the flue on the drawing. That establishes a scale whereby we can deduce an economizer dimension which cannot be far wrong. The heating surface is stated specifically in the article itself as well as the length of the economizers. The height and width have to be scaled from the complete dimensions. The width of the flue or casing is all we have to go by. I included all the space occupied by the return bends at the bottom but did not include the headers or any of the return bends in that apparatus.

497 I do not find anything in claim 2 of the Bell patent that warrants my statement that he gave clear instructions with regard to the ribbed tubes, their horizontal disposition and location as close to each other as was practical, with the deliberate purpose of incurring higher draft loss. I do find it in the specification in his specific reference to a draft loss of 3 or 4 or 5 inches, which is a huge loss in comparison with anything in the record as appearing elsewhere. The connection between that draft loss and the structure referred to in the claim I find in the compact arrangement of the heating surface.

When I quoted in my testimony from the Bell patent with
498 regard to a draft suction at normal load as high as 3, 4, or 5 inches of water, I stopped there for the sake of brevity. I see that I laid myself open to misunderstanding since 3, 4, or 5 inches of draft loss is not the draft loss in the economizer, but in the entire apparatus, including the furnace. That correction does not affect at all the statements which I made in that connection because if you merely take 50 percent of those figures you still have a draft loss which is huge in comparison with the draft losses which apply to the prior

disclosures which have been alleged here as prior anticipations. Compare that with Kablitz, who in one paper, and in his later paper, mentions a draft loss of $\frac{1}{6}$ of an inch. This is $\frac{1}{15}$ of the larger figure mentioned mentioned by Bell if we assume that only a little more than half is assignable to the economizer. I do not agree with Professor Marks that the draft loss per se is a detriment and not an advantage. I do agree that that was the widespread, if not the universal, idea of draft loss previous to Bell's application. 499

A horizontal baffle extending three-quarters of the way across the flue would increase the draft loss, but you would get no advantage from it. What Bell had in mind when he spoke of draft loss was increased velocity of the gas over the tubes; he certainly had that in mind, but it is not anything different from the question of draft loss. When Bell said "draft loss" he was talking about this advantage to be gained by increased velocity over the tubes provided that increased velocity is developed in the manner which he specifies. 500

I believe that an economizer having an extended surface as described in the Bell patent, with staggered tubes and spacing as defined in the claim, but having a low draft loss, would be a poor embodiment of the Bell patent, but if it followed Bell in every other respect except that the draft loss was less than what he specified, it would come within the Bell invention. 501

[Counsel for plaintiff offers in evidence file wrapper and contents of the Bell patent in suit as "Plaintiff's Exhibit No. 16".]

502

Defendant's Proofs in Sur-Rebuttal.

ERNEST B. FREEMAN, a witness called on behalf of the defendant in sur-rebuttal, having been previously duly sworn, testified as follows:

Direct Examination by Mr. HILDRETH.

From my experience as an executive of B. F. Sturtevant Company, and familiar with the practice of that company, there would be no difficulty in casting tubes substantially 2 inches in diameter and of a length of 10 or 12 feet with flanges similar to those shown in the Dietrich patent. I say
503 that because we bought thousands of 2-inch tubes with bell ends anywhere from 8 to 12 feet in length, and we used hundreds of them that we made ourselves in a pony economizer that was shorter that was brought out in 1906. Bell ends constituted projections just as ribs do.

Cross Examination by Mr. McKNIGHT.

These tubes were not all plain smooth surface tubes with a flange at each end. In some cases, because of their application, there were four ends, two near the center about 6 inches apart, and one on either end. These were 12 feet long. Our company did not make them but they were made for us by the Warren Foundry Machine Company.

504

Redirect Examination by Mr. HILDRETH.

We had no tubes with longitudinal flanges. They were all what we call bell ends or flanges, four on a tube. They were ribs, not longitudinal fins. I do not believe there would be the slightest difficulty in casting such tubes with flanges along their length. I have operated foundries for 15 years, and in fact I think the ribs would aid the casting and you would have less losses.

PLAINTIFF'S EXHIBIT 1.

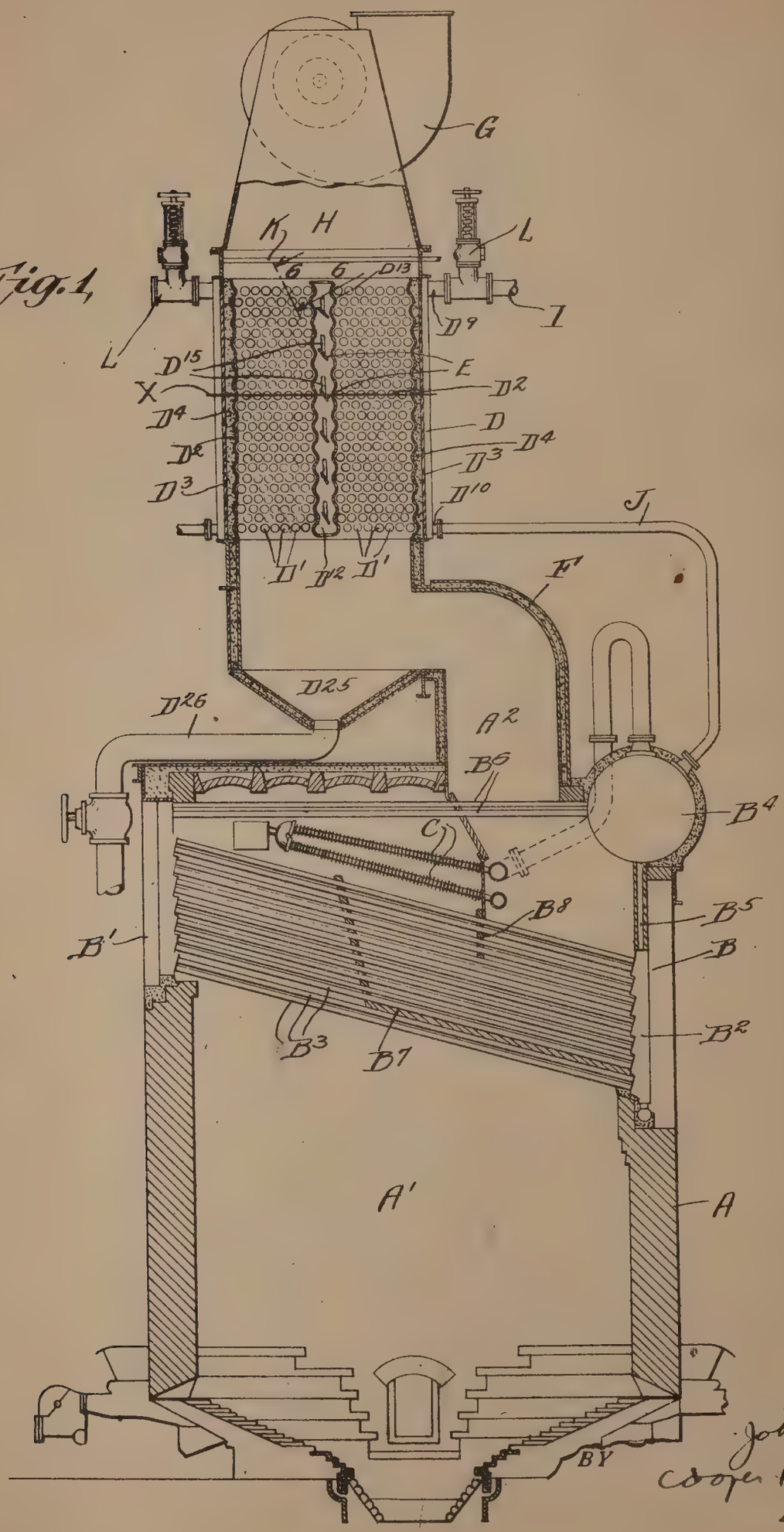
Dec. 15, 1925 1,565,305

J. E. BELL

STEAM GENERATING PLANT

Filed July 1, 1922 3 Sheets-Sheet 1

Fig. 1



INVENTOR
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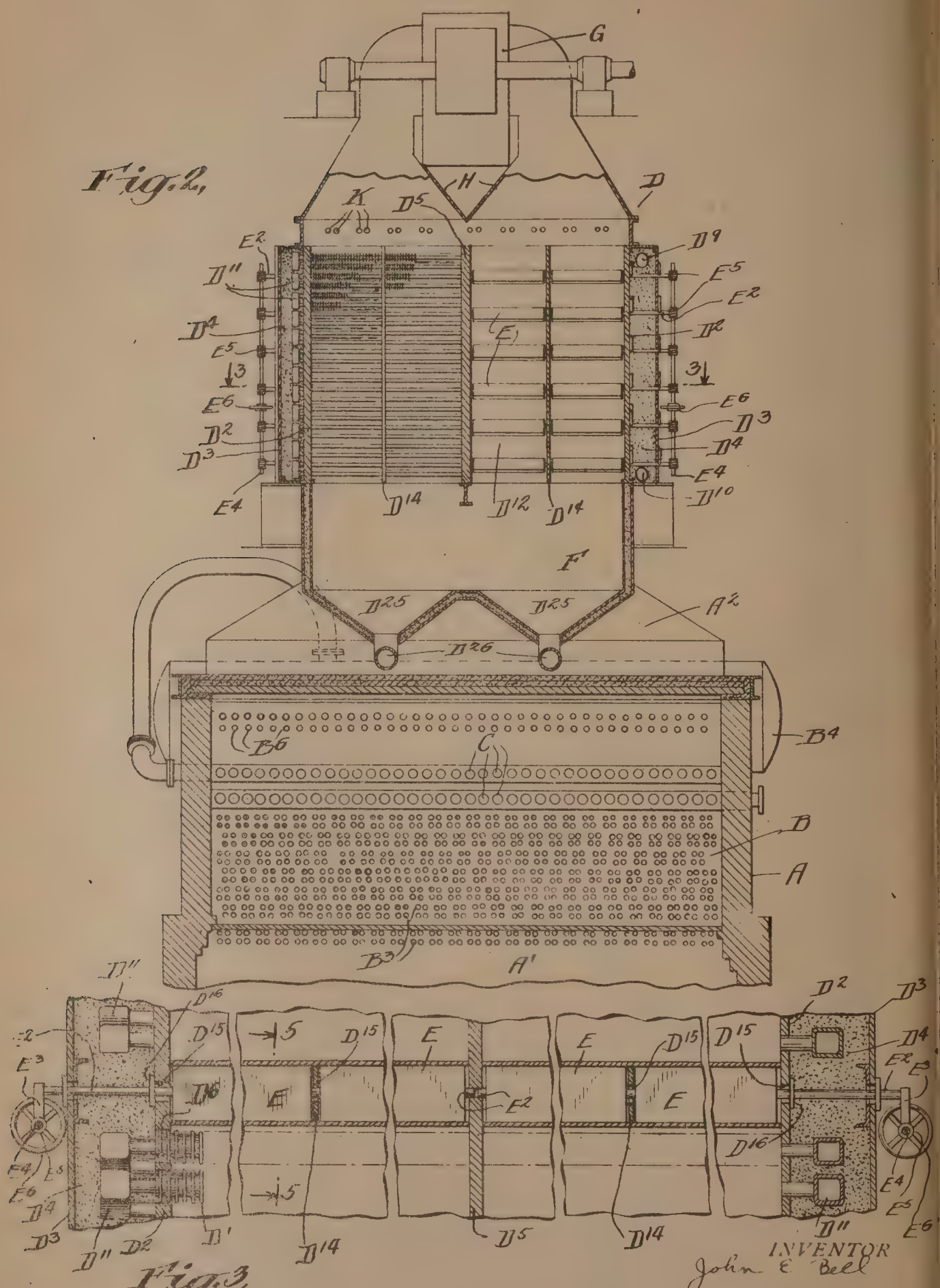
Dec. 15, 1925 1,565,305

J. E. BELL

STEAM GENERATING PLANT

Filed July 1, 1922 3 Sheets-Sheet 2

Fig. 2,



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Dec. 15, 1925 1,565,305

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STEAM GENERATING PLANT

Filed July 1, 1922 3 Sheets-Sheet 3

Fig. 5,

Fig. 4,

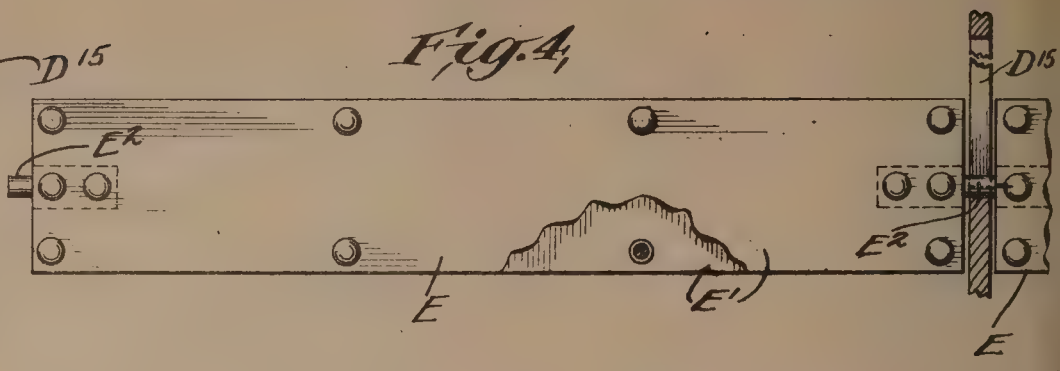
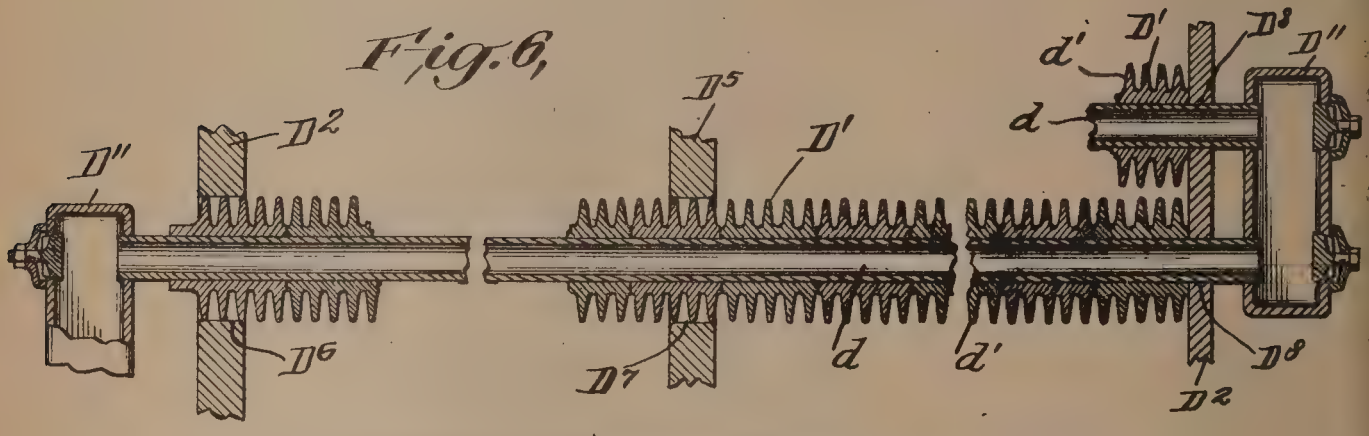


Fig. 6,



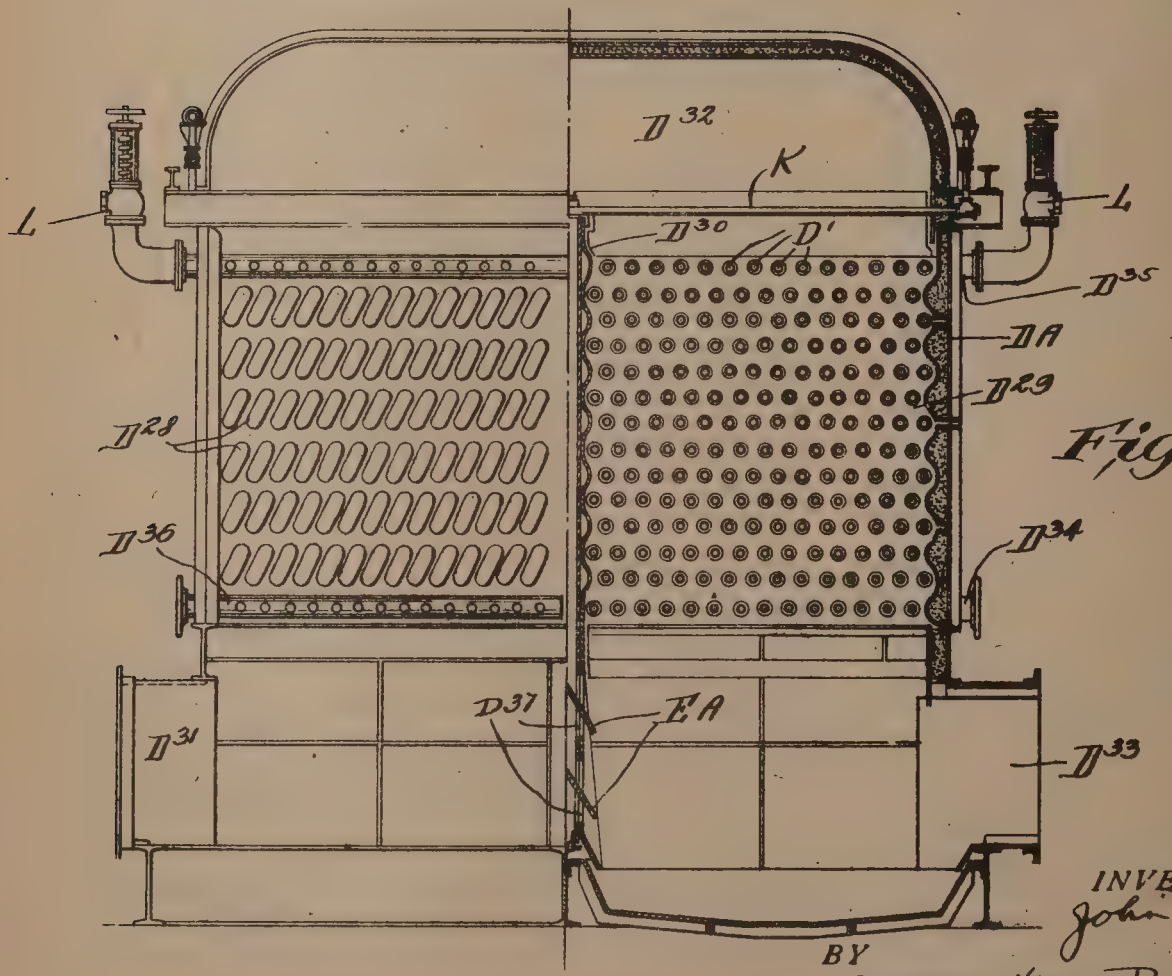


Fig. 7,

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'atented Dec. 15, 1925. 1,565,305

UNITED STATES PATENT OFFICE.

JOHN E. BELL, OF BROOKLYN, NEW YORK, ASSIGNOR TO POWER SPECIALTY COMPANY, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

STEAM-GENERATING PLANT.

Application filed July 1, 1922. Serial No. 572,166.

To all whom it may concern:

Be it known that I, JOHN E. BELL, a citizen of the United States of America, residing at Brooklyn, county of Kings, and State of New York, have invented certain new and useful Improvements in Steam-Generating Plants, of which the following is a full, clear, and exact description.

The general object of my invention is to provide improvements in method of, and apparatus for generating steam. More specifically the object of my invention is to provide for the more effective utilization of an economizer for transferring heat to boiler feed water from the partially cooled products of combustion leaving the boiler furnace.

It has long been common practice to preheat boiler feed water by the use of an economizer, but heretofore the economizer has ordinarily been regarded as an adjunct of the boiler, which, while of value, is distinctly of secondary importance as compared with the boiler proper. I have discovered, however, that highly beneficial results, both with respect to the thermal efficiency and operating economy of a steam generating plant, and with respect to the initial construction and maintenance costs, may be obtained by making the economizer a more important element of the steam generating plant than has heretofore been the case.

To this end I substantially increase the ratio of economizer heating surface to boiler heating surface over that heretofore employed in commercial practice, and provide the economizer heating surface in an economizer of special construction characterized by its compactness and requiring a draft much stronger than is required in the types of economizers heretofore in use to move the heating gases through it. In the preferred practical mode of carrying out my invention I employ economizer tubes similar in construction to those heretofore employed in the well known Foster superheater, in that each tube comprises an inner tube of wrought steel which is surrounded by an externally corrugated tubular cast iron casing. In the economizer which I employ, the special tubes are preferably spaced closely enough together to give an aggregate external tube surface area per unit of volume of space occupied which is several times greater than is obtained or is practically possible of attainment in economizers of the types heretofore in commercial use. The compactness of the economizer which I employ not only reduces the bulk and initial cost of the economizer but makes it practically feasible to enclose the economizer in a housing which forms part of the boiler setting and is sufficiently air tight to practically eliminate air leakage into the economizer, notwithstanding the high draft suction impressed on the economizer.

The special economizer tube construction employed provides a very large amount of external heating surface swept by the heating gases, in comparison with the internal wet surface of the tube; is well adapted for high pressure work since the steel inner tube may readily be of sufficient strength to resist an internal pressure as high or higher than the boiler steam pressure, and the cast iron casing section protects the steel inner tube from the corrosive effect of the furnace gases which rapidly destroy steel economizer tubes directly exposed to the action of the heating gases, especially in the low temperature portion of an economizer.

Heretofore in ordinary practice, the ratio of economizer heating surface to boiler heating surface has not been greater than the ratio of 7 to 10. In accordance with my present invention I make the economizer heating surface at least as great as and in some cases considerably greater than the boiler heating surface. In thus increasing the ratio of economizer to boiler heating surface in a steam generating plant of given capacity, I make the amount of economizer heating surface greater and the amount of boiler heating surface smaller than has heretofore been used in a steam generating plant of similar capacity and efficiency. The increase in economizer heating surface made is less however than the decrease in boiler heating surface as my invention permits of a smaller aggregate boiler and economizer heating surface than has heretofore been required. The explanation of this saving in total heating surface is found in the fact that the decrease in boiler and increase in economizer heating surface tends to increase the average temperature differential between the boiler heating surface and the heating gases passing through the boiler, and also between the economizer heating

surface and the heating gases passing through the economizer. The maximum theoretical reduction in total heating surface would be obtained by increasing the ratio of economizer to boiler heating surface to the point at which the water would be heated in the economizer to the boiler steam temperature, but in practice I consider it desirable to maintain the maximum economizer water temperature below the boiler steam temperature under normal conditions of operation.

The rate at which a heated gas gives up its heat to a cooler surface is, as well-known, almost directly proportional to the velocity of flow of the gas over the surface, or more strictly speaking, to the product of the velocity times the gas density, or the mass flow. It is also a function of the temperature of the gas and increases very materially for gas temperatures corresponding to furnace temperatures. This increase is not only due to the greater difference in temperature between the gas and the absorbing surface, which is, of course, of a high order, but is also due to an increase in the transfer rate per degree difference in temperature. Heat absorbed by radiation from the furnace is roughly proportional to the fourth power of the absolute temperature of the furnace. In the case of first impingement of the furnace gases and before a uniform temperature gradient has been established, I have found that the heat transmitted by convection, or contact between the gases and the cooling surface is at a rate of transfer of approximately the same order as that due to radiant heat. It follows therefore, that in a boiler, still or other apparatus, which absorbs heat from furnace gases, that the bulk of the heat so absorbed, which corresponds to high gas temperatures, is absorbed in such a manner as to make the velocity of the gases over the surface relatively unimportant. The same condition does not, however, exist in connection with the absorption of the heat given out at the lower gas temperatures, where the velocity is the controlling factor. I, therefore, propose arranging my boiler surface, which as has been pointed out, is relatively of very much smaller extent than has heretofore been used, without regard to gas velocity, and arrange the economizer surface, which is much larger than heretofore used, to obtain the maximum allowable velocity compatible with the draft conditions. This necessitates a comparatively small draft loss in the boiler portion, and a corresponding larger draft loss in the economizer portion to obtain the maximum temperature reduction with a given draft suction at the economizer outlet. The tubes should be horizontally disposed to restrict the tendency of furnace dust to deposit on the sides of the corrugation ribs and to facilitate cleaning the tub. Furthermore, the tubes should extend tra versely to the direction of flow of the he ing gases and should be arranged in ro substantially transverse to the direction flow of the heating gases, with the tubes adjacent rows staggered; and the tub should be closely spaced so that the avera distance between tube centers is small, f example in the neighborhood of one and o quarter times the maximum tube diamet and the area of the gas path between a pa of adjacent tubes in adjacent rows trar verse to the direction of the gas flow shou not be less than one half the area of the g path between adjacent tubes in the sa row, to insure proper contact between t heating gases and the tubes, and to mir mize the frictional resistance to the flow the heating gases through the economiz and thereby minimize the draft required move the heating gases through the bank the economizer tubes.

Where, as will ordinarily be the case, t high draft suction required for operating steam generating plant in accordance wi the present invention cannot be provided stack or natural draft but requires an e haust fan, I have found it advantageous make provisions for sending a portion on of the furnace gases leaving the boil proper through the economizer when t steam generating plant is operatiang und peak load conditions. The diversion of portion of the furnace gases away from t economizer under peak load conditions pe mits of the use of an exhaust fan of small capacity than would otherwise be require with a consequent decrease in initial and o erating costs, and great economy in oper tion under normal loads. Moreover, the version of a portion of the furnace gas away from the economizer, under peak lo conditions, does not result in a correspon ing decrease in the temperature to whic the feed water is heated.

Where, as is frequently the case, the ge eral direction of flow of the heating gas is upward through an economizer or econ mizer section, which comprises a bank horizontally disposed tubes, the temper ture of the water in the tubes should i crease progressively from the initial wat temperature at the top of the bank to maximum delivery temperature at the bo tom of the bank. To obtain this result is not only necessary to have the water flo back and forth through economizer tubes successively lower levels, but it is also ne essary, as I have discovered, to have a v locity of water flow through the economiz tubes which is not less than a certain crit cal velocity. If the velocity of the wate flow is less than this critical velocity para sitical or convection currents will be set u

in the water in the economizer tubes which will make the temperature in the tubes at the top of the bank practically as high as the temperature in the tubes at the bottom of the bank.

Where, in an economizer, the water flows serially through a plurality of tubes, and the conditions of operation are such as to maintain a fairly definite water temperature gradient along the path of flow, as is the case in an economizer comprising a bank of horizontally disposed tubes in which the water flows serially through tubes at successively higher levels, or flows serially at the proper velocity, as above explained, through tubes at successively lower levels, there is obtained the advantage that the corrosive effects which occur mainly at a particular water temperature are substantially restricted to the tubes normally at that temperature, and are not distributed over all or a considerable portion of the tubes in the bank. This is particularly important in connection with the corrosive action on the inner surfaces of the tubes due to air contained in the water. As is well known, water which is exposed to the atmosphere at ordinary atmospheric temperatures holds in solution a considerable amount of air and when such water is heated, the air is liberated. In the case of an economizer the oxygen in the liberated air attacks or corrodes the inner surface of the economizer tubes when the latter are made of a ferrous material such as wrought iron or steel. The water temperature at which the liberated air thus attacks the economizer tubes is believed to be 180° or thereabouts. By arranging and operating an economizer so that this critical water temperature of 180° or so, is normally maintained in the economizer tubes in one or two rows only, and making the tubes subject to this corrosive action readily removable, it follows that the destructive effect of air in the water is restricted to a comparatively few number of tubes which may be readily replaced without disturbing the large majority of uninjured tubes.

My invention comprises methods of and apparatus for effectively utilizing the above mentioned discoveries and principles of operation. The various features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, however, its advantages and specific objects obtained with it, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described preferred embodiments of my invention.

Of the drawings:

Fig. 1 is a side elevation partly in section of one form of steam generating boiler and economizer arrangement;

Fig. 2 is an elevation partly in section taken at right angles to Fig. 1;

Fig. 3 is a partial plan on the line 3—3 of Fig. 2;

Fig. 4 is a view taken on a larger scale than Fig. 3 showing a portion of the damper arrangement of Fig. 3;

Fig. 5 is a section on the line 5—5 of Fig. 3;

Fig. 6 is a partial section on the line 6—6 of Fig. 1; and

Fig. 7 is an elevation partly broken away and in section of a modified form of economizer arrangement.

In the drawings, and referring first to the construction shown in Figs. 1 to 6, A represents a boiler furnace of conventional type, with a water tube boiler B, above the furnace combustion chamber A′. The boiler B as conventionally illustrated, comprises front and rear headers B′ and B^2 connected by inclined water tubes B^3, and a steam and water drum B^4 to which the rear headers are connected by conduits B^5, and to which the front headers B′ are connected by horizontal tubes B^6. Baffles B^7 and B^8 cause the furnace gases to travel across the water tubes in a plurality of passes from the combustion chamber A′ to the furnace gas outlet A^2. C are superheater tubes located in the space between the tubes B^3 and B^6 and between the first and second passes for the furnace gases.

Mounted above the boiler furnace proper is the economizer D which, in the construction illustrated, comprises two vertically elongated banks of horizontally disposed economizer tubes D′. The tubes D′ are enclosed in a housing which, in the preferred construction illustrated, comprises an inner metallic shell D^2 and an outer metallic shell D^3 with a space D^4 between the two shells which is filled with a suitable material such as powdered Sil-o-cel which serves both as a heat insulating material, and also as a packing preventing leakage through the joints in the shells D^2 and D^3. The tubes D′ each comprise an inner tube *d* of wrought steel and an externally corrugated tubular casing *d′* formed of cast iron sections which fit snugly on, and may be shrunk in place on the tubes *d*. Various provisions may be made for supporting and connecting the different tubes D′. In the simple and effective construction illustrated, the tubes D′ are supported in the end walls of the shell D^2 and in an apertured tube sheet D^5 placed midway between the end walls. One of the end walls is formed with apertures D^6 a trifle larger than the maximum diameter of the tubes D′, so that the latter may be axially removed from, and replaced in the housing through these apertures when con-

ditions make this desirable. The tube sheet D^5 is formed with tube receiving apertures D^7 similar to the apertures D^6. The apertures D^8 formed in the opposite end wall of the economizer housing are only large enough to receive the bare ends of the inner tube portion d of the tubes D'. The tubular casings d' of the tubes D' abut against the inner side of the end wall of the portion of the shell D^2 in which the holes D^8 are formed, and at the opposite end of the economizer, the ends of the casings d' may well be substantially flush with the outer surface of the portion of the shell D^2 in which the holes D^6 are formed.

In the construction illustrated the tubes D' in the top row of each economizer bank, each has one end expanded or otherwise secured in a supply header D^9. Similarly the bottom row tubes D' each have one end expanded or otherwise connected to the outlet header D^{10} of the economizer. In the particular construction shown, each of the economizer tubes in each intermediate row of the economizer is connected at one end by a return bend D^{11} to the corresponding end of the tube D' in the row immediately above, and has its opposite end connected by a return bend D^{11} to an economizer tube in the subjacent row. As shown in Fig. 1 the economizer tubes in adjacent rows are staggered, and the side walls of the shell D^2 are advantageously corrugated as shown in Fig. 1 in conformity to the staggered arrangement of the tubes D' so as to restrict the flow of the heating gases through the spaces between the side walls and the adjacent tubes D'.

The two banks of economizer tubes are separated by a passage D^{12} which advantageously is formed with metal side walls D^{13} corrugated to conform to the staggered arrangement of the tubes D'. The passage D^{11} forms a by-pass through which a portion of the heating gases may be passed under peak load conditions. Flow through the by-pass passage D^{12} may be controlled by a damper or dampers of any usual or suitable form. Preferably, however, the special damper arrangement comprises a plurality of horizontally extending dampers E arranged one above the other in the passage D^{12}. Each of these dampers may be rotated from a vertical wide open position, into a horizontal closed position. In some cases each damper E may extend the full horizontal depth of the channel D^{12}, but in the construction shown, this channel is subdivided into four flues by the tube sheet D^5 and intermediate division walls D^{14}, and four dampers E, one for each flue, are provided at each damper level in the economizer. Each damper E may advantageously be formed, as shown best in Figs. 3, 4 and 5, of spaced apart sheet metal plates E' connected together, and each damper is provided at its ends with a suitable pintle or spindle extension E^2 which is journalled in the corresponding division or end wall of the channel D^{12}. As shown, the two aligned dampers at each side of the central division wall D^5 are connected by a common pintle or spindle part E^2, and each damper adjacent the end wall of the channel D^{12} has its corresponding pintle E^2 projecting through the end wall and provided with an external operating connection. The operating connections for the dampers E shown, comprise a gear segment E^3 connected to the outer end of each externally projecting pintle E^2, and an operating shaft E^4 at each end of the economizer provided with worm sections E^5 in mesh with the corresponding gear segments E^3. As shown each shaft is provided with a hand wheel E^6 by which it may be rotated to open and close the corresponding dampers. In its closed position each damper section extends into close proximity to the adjacent portions of the by-pass side walls D^{13} (see Fig. 5) but need not make a perfectly tight joint with the latter since, in accordance with the principle involved in the ordinary labyrinth packing, the series of dampers E in each flue portion of the by-pass serve, when closed, to prevent any appreciable flow through that flue portion, even though the joints at the edges of any one damper E in the series are open enough to permit an appreciable flow through those joints if subjected to the pressure differential at the opposite ends of the flue.

The fact that in the by-pass damper arrangement described no one of the series of dampers E provided need actually seal the by-pass greatly simplifies the construction and operation of the dampers, especially since with this construction, contraction and expansion or distortion of the parts resulting from the varying temperatures to which they are subjected do not interfere with the operation or effectiveness of the dampers. To permit the removal and replacement of the dampers the central division wall D^5, the intermediate division walls D^{14} and the portions of the shell D^2 at the ends of the by-pass channel D^{12} are formed with slots D^{15} large enough to permit the passage therethrough of the dampers when the latter are vertically disposed and are raised upward from their normal positions in which the pintles E^2 rest against the bottom edges of these slots. Removable covers D^{16} may be provided for the slots D^{15} in the shells D^2 and D^3, but the slots D^{15} in the division wall D^5 and intermediate walls D^{14} need not be closed.

The connection F between the economizer housing proper and the boiler housing for passing the furnace gases to the economizer from the boiler housing outlet A^2 is advan-

geously formed, similarly to the economizer housing, with inner and outer metallic shells and insulating material between the shells.

Above the economizer is located an exhaust fan G for creating the draft suction required to move the furnace gases through the boiler and economizer at the desired velocity. The connection H between the exhaust fan casing proper, and the economizer housing is advantageously formed of metal which need not be insulated as heat radiation from the shell is desirable since it reduces the temperature and volume of the gases passing from the economizer and the heat thus lost would not be utilized in the apparatus in any event.

The feed water is supplied to the economizer by a supply pipe I ordinarily connected to the outlet of a boiler feed pump (not shown). The pipe I is connected to the top economizer header D^9, and the boiler feed water is forced through the economizer tubes and into the boiler against the pressure of the latter through the conduit J connecting the bottom economizer header D^{10} to the steam and water drum B^4. In many cases I prefer to employ a boiler feed controller automatically regulating the flow of feed water into the boiler in response to the requirements, and this may operate in a known manner either to directly control the delivery of water to the economizer, or to directly control the flow of water from the economizer into the boiler. In any event the pressure of the water in the economizer tubes must be as high as, and in some cases may be appreciably above the pressure in the steam and water drum B^4 of the boiler, which will ordinarily be 250 pounds or above, in steam generating plants constructed in accordance with the present invention.

With the special form of economizer tube shown, the internal steel tube *d* provides the strength to resist the internal pressure to which it is subjected, while the cast iron casing *d'* is to a large extent immune to attack by the furnace gases, and such pitting or other injury as it may receive in time from the corrosive effect of the furnace gases does not weaken the resistance of the tubes to the internal bursting pressure to which they are subjected, and does not appreciably effect the heat absorbing capacity of the cast iron casing. This heat absorbing capacity is of course greatly enhanced by the relatively great amount of external heating surface in contact with the furnace gases which it provides. The area of external gas swept heating surface of each tube may advantageously be in the neighborhood of 5½ to 6½ times as great as in the internal wet surface area of the tube.

In the construction shown in Figs. 1 and 2 the externally corrugated economizer tubes D' are arranged in horizontal rows which extend transversely to the general direction of gas flow past them, and are also arranged in rows extending parallel to the general direction of gas flow, the tubes in the adjacent horizontal or transverse rows being staggered. The tubes D' are closely spaced. In ordinary practice I prefer to make the average of the distances between the centers of each tube D' and the centers of the immediately adjacent tubes about one and one quarter times the maximum tube diameter. Notwithstanding the small space between the exterior surfaces of the economizer tubes, the internal tubular parts *d* are sufficiently far apart to permit the ready use of suitable end connections between the different tubes, since these connections are external to the inner metal shell D^2 of the economizer housing, and the tube casings *d'* need not project through the shell D^2. With this spacing the external heat absorbing surface if the economizer per unit of space occupied by the bank of economizer tubes is several times greater than is practically possible with economizer tubes of the same internal diameter and having smooth external walls, especially since with the smooth walled tubes the minimum distance between the tubes is limited by the necessity for providing space for the necessary end connections to the tubes.

Suitable provisions should be made for blowing or washing dust off of the economizer tubes at sufficiently frequent intervals. In the preferred construction illustrated, the provisions for this purpose comprise water spray pipes K horizontally disposed above the banks of economizer tubes and extending transversely to the tubes, and suitable connections for supplying water at intervals to these spray pipes. Advantageously the water supply connections are arranged so that water is discharged from only a few of the pipes K at a time, to thereby avoid undue cooling of any one economizer tube as a whole, and to avoid the disturbance in draft conditions which would be created by the very considerable volume of steam which would be generated if water were simultaneously discharged from all of the spray pipes K. Suitable pockets D^{25} may advantageously be provided, as shown, at the bottom of the economizer housing to receive the clean-off water and dust with valved drain pipe connections D^{26} discharging from the pockets.

In the contemplated construction and mode of use of the apparatus shown in Figs. 1 to 6, the aggregate heating surface of the economizer swept by the heating gases is at least as great as the aggregate heating surface of the boiler proper so that a much larger portion of the total amount of heat

abstracted from the heating gases is absorbed by the economizer than has been the practice heretofore where the economizer heating surface has ordinarily been 70% or less of the boiler heating surface. The distribution of boiler and economizer heating surface which I employ makes it possible to obtain a relatively high amount of superheat with a superheater of moderate size located above the main bank of water tubes.

The close spacing of the economizer tubes, and their corrugated exterior surfaces provide tortuous gas paths through which the heating gases move with relatively high velocity thus insuring a high heat transmission factor and a large economizer capacity per unit of volume. The consequent comparatively small economizer volume required for a given duty makes it practically feasible to employ an economizer housing which is substantially air tight, thus practically eliminating air leakage into the economizer notwithstanding the comparatively high draft suction required to move the heating gases through the boiler and economizer. Air leakage is objectionable both because of the cooling effect of the air leaking in, and also because of the resultant increase in volume of the gases which must be handled by the draft creating fan. Air leakage tending to increase the exhaust fan capacity required is especially objectionable in the practice of my invention because the relative high draft suction which I ordinarily employ requires a considerable expenditure of fan driving energy at normal load even when there is no leakage at all. It has heretofore been the practice to operate a boiler plant comprising an economizer with a draft suction which ordinarily does not exceed one and three quarter inches of water, at a maximum. In proceeding in accordance with the present invention I may advantageously employ a draft suction at normal load as high as three, four, or five inches of water, and of which much more than half is utilized in moving the heating gases through the economizer.

The relatively high draft suction at normal load which I prefer to employ, makes the economizer by-pass D^{12} of especial importance, as becomes apparent when account is taken of the great increase in exhaust fan capacity and driving power which would be required if all the heating gases were drawn through the economizer under the peak load conditions which may prevail for an hour or so out of each twenty-four hours of service. Assume, for example, a plant in which the boiler heating surface proper is ten thousand square feet, and the normal load involves operation of 400% of rating, while for an hour or so out of each twenty-four hours, the boiler must be operated at 640% of rating; and also assume that when operating at normal load, the draft suction at the fan inlet is three inches, and 20 H. P. is required to operate the fan. On the further assumption that the fan inlet temperatures are the same at peak load as at normal load, the volume of heating gases to be handled by the fan under peak load conditions, will be eight-fifths of that handled at normal load. To move this increased volume of gases through the boiler and economizer the fan inlet suction must be increased from three inches to

$$\left(\frac{8}{5}\right)^2$$

times three inches or about seven and two-thirds inches. The fan driving force required for operating the fan at the increased load will be increased in proportion to the product of the volume of gas handled and the suction required to move the gas; in other words, the driving force required for the fan under peak load conditions will be, not 20 H. P., but

$$\left(\frac{8}{5}\times\frac{8}{5}\right)^2$$

times 20 H. P., or about 82 H. P. Actually the temperature of the gas at the fan inlet will be higher under peak load conditions than under normal load conditions, and this involves some further increase in the power required to operate the fan. If, instead of passing all the heating gases through the intertube space of the economizer under the peak load conditions assumed, a third of the heating gases are then drawn through the by-pass D^{12}, the volume of gas drawn through the economizer under the peak load conditions will be sixteen-fifteenths (i. e.

$$\left(\frac{8}{5}\times\frac{2}{3}\right),$$

of the volume of gas at normal load; the draft suction necessary to move this gas through the economizer will be about one and one-eight (i. e.

$$\left(\frac{16}{15}\right)^2$$

times the suction required to move the gas through the economizer at normal load; and the fan driving force required to move the gas through the economizer will be a little over 24 H. P. (i. e.

$$\left(\frac{16}{15}\right)^3\times 20\text{ H. P.}$$

Furthermore, on account of the higher temperature of the gases entering the economizer under peak load conditions, and the greater velocity of gas flow through the economizer, the portion of the heating gas flowing through the economizer at peak load with the by-pass D^{12} open will heat the

boiler feed water in the economizer up to, or nearly to the temperature to which it is heated in normal operation.

The effective utilization of my compact economizer requires a progressive graduation in temperature of the water flowing through the economizer from the water inlet temperature at the top of the economizer, to the delivery temperature at the bottom of the economizer. I have found that this result can be obtained in an economizer in which the general direction of flow of water through a bank of horizontally disposed tubes is downward, only when the velocity of water flow through the economizer tubes is equal to, or above a certain critical velocity.

If the velocity of water flow through the economizer tubes is less than this critical velocity, there is a tendency to the maintenance of parasitical or convection currents in the water in the tubes substantially equalizing the water temperature throughout the economizer tube system, so that the temperature in the upper economizer tubes will be practically as high as the temperature in the lower tubes of the economizer. The exact critical velocity which must be equaled or exceeded to insure the desired temperature graduation from top to bottom of an economizer in which the water flow is downward depends upon a number of factors, some of which are difficult to predetermine with precision. The critical velocity may be readily determined experimentally however in the case of any particular economizer and set of operating conditions, and by way of example I will state that in the case of a steam generating plant such as that shown in Figs. 1 and 2, operating at 250% of rating, and with a boiler pressure of 250 pounds and with the economizer tubes of two inches internal diameter, the critical velocity of water flow through the tubes of the economizer is in the neignborhood of one half foot per second. For the practical utilization of this feature of my invention I connect the tubes of the economizer so that the normal rate of flow through the economizer tubes at the lowest rate of evaporation at which it is contemplated to operate the boiler for any considerable portion of the time will be at least as high as the critical velocity. It is apparent, of course, that the velocity of flow through the economizer tubes depends on the number of separate paths of flow provided between the economizer inlet and outlet. Thus in the economizer in which there are fourteen economizer tubes in each horizontal row, if the economizer tubes are connected (as shown in Figs. 1 and 2) so that each tube in one row is separately connected to a tube in the adjacent row there will be fourteen paths of flow between the economizer inlet and economizer outlet. If the tubes in each horizontal row were connected in pairs so that the water entering one end of a tube would pass through that tube to the opposite end of the economizer, and would then return through another tube in the same row before passing to a tube in a lower row, there would be but seven paths of water flow through the economizer, and the velocity of flow for a given quantity of water flowing would be twice as great as in the instance first given. As already explained, the effect of maintaining a definite graduation of water temperature in the economizer tubes is to confine the internal corrosive action of liberated air to the comparatively few tubes in which the normal temperature is that at which the corrosive action mainly occurs. Thus, if in the economizer shown in Fig. 1, the temperature in the tubes at the level indicated by the line X, is normally about 180°, the corrosive action of liberated air will be mainly confined to the tubes at that level. With the described method of mounting and connecting the tubes, it will be apparent to those skilled in the art that any particular tube or tubes may be readily replaced. With the particular form of end connections illustrated, the replacement of the tube elements involves cutting off the ends of the inner tubes *d* of the corresponding elements which are readily accessible for this purpose, after which the elements are axially removed through the openings D^6 and D^7 in the tube supporting walls D^2 and D^5, respectively. It will be understood, of course, that the metallic outer wall D^3 is formed with removable sections to permit tube replacements, but the particular provisions made for this purpose form no part of my present invention and hence are not illustrated herein.

In Fig. 7, I have shown a modified form of economizer in which the economizer tubes D′ are arranged in two banks D^{28} and D^{29} separated by a partition D^{30} and arranged in an economizer housing provided with an inlet D^{31} for heating gases opening to the under side of the tube bank D^{28} and with a chamber D^{32} through which the heating gases pass from the top of the bank D^{28} into the top of the bank D^{29}, and with an outlet D^{33} for the spent heating gases opening from beneath the tube bank D^{29}. The external walls of the housing of the economizer DA may be similar in construction to the housing walls of the economizer D. In the economizer DA the water to be heated passes initially through the header D^{34} into the tubes D′ in the lower row of the tube bank D^{29}. Thence the water passes upward through the tubes in the bank D^{29} to a top header D^{35} to which the various tubes in the top rows of both tube banks D^{28} and D^{29} are connected. From

the header D^{35} the water passes downward through the tubes in the bank D^{28} to the header D^{36} to which the tubes in the lower row of the bank D^{28} are connected. From the header D^{36} the water may pass to the boiler through suitable connections not shown.

In each of the tube banks D^{28} and D^{29} of the economizer DA the general direction of water flow is counter to the flow of the heating gases through the intertube space of the tube bank. To obtain the full advantage of this counter flow, the velocity of water flow through the tubes in the bank D^{28} must be equal to or exceed the critical velocity previously mentioned. In so far as the bank D^{29} is concerned, however, the desired water temperature graduation from bottom to top of the bank will be obtained regardless of the velocity of flow through the individual tubes of the tube bank, and the tubes D′ of the bank D^{29} may be so connected as to give a flow velocity through them which is less than the critical velocity if condition makes this desirable.

In the economizer DA, ports D^{37} are formed in the portion of the wall D^{30} beneath the two banks D^{28} and D^{29}. Dampers EA are provided to regulate the flow of heating gases through the ports D^{37} which thus provide a by-pass about both banks of economizer tubes between the inlet D^{31} and outlet D^{33} through which a portion of the heating gases may be passed under peak load conditions. To avoid all possibility of undesirable steam and air accumulations in the top economizer headers, and to guard against excess pressure in the economizers, the top header D^{9} of the economizer D, and the top header D^{35} of the economizer DA may each be provided with one or more pressure relief or safety valves L.

Certain novel features of construction and arrangement disclosed but not claimed herein are claimed in my co-pending application, Serial No. 336,284, filed November 7, 1919, of which this application is, in part, a continuation.

While in accordance with the provisions of the statutes, I have illustrated and described the best forms of carrying out my invention now known to me, it will be apparent to those skilled in the art that changes in the form of the apparatus and modes of operation described herein may be made without departing from the spirit of my invention as set forth in the appended claims, and that certain features of my invention may sometimes be used to advantage without a corresponding use of other features.

Having now described my invention, what I claim as new and desire to secure by Letters Patent, is:

1. In a steam generating plant comprising a boiler furnace and a boiler section having storage capacity for a variable amount of water, and having a steam and water space, the improvement which consists in an economizer section traversed by the boiler furnace heating gases after the latter have left the boiler section and through which water is passed into the boiler section, and formed of staggered rows of steel tubes encased in externally corrugated tubular cast iron sections, said tubes being so proportioned as to provide an aggregate economizer heating surface approximately as great as the aggregate boiler heating surface, and so spaced as to require a draft suction at normal load to move the heating gases through the economizer section at least as great as the draft suction required to move the heating gases through the boiler section.

2. The combination with a boiler and its furnace, of an economizer comprising a bank of horizontally disposed tubes externally swept by the heating gases leaving the furnace and through which feed water is passed into the boiler, said tubes being each provided with external circumferentially extending ribs proportioned and disposed to make the external surface area of the tube several times greater than its internal surface area, and being each of a length many times greater than its maximum diameter, and being spaced to provide an external tube surface area per unit of space occupied by said bank which is several times greater than is practically possible with tubes which are of the same internal diameter and have smooth outer walls.

3. The combination of claim 2 further characterized by the fact that each of the economizer tubes comprises an inner thin walled steel tube, and a cast iron casing therefor of tubular form and externally corrugated.

4. In apparatus of the kind described, the combination with a bank of tubes having external circumferentially extending heat absorbing ribs on their body portions and having bare ends, a gas passage traversed by said tubes and having opposed metallic walls in which the ends of the tubes are supported and from the outer sides of which the bare ends of the tubes project, one of the walls having tube openings of a size to permit the longitudinal passage of the ribbed portions of the tubes, return connections to which the bare ends of the tubes are secured, and heat insulating material in which the portions of said tubes projecting through said walls and said return connections are embedded, and which engages the outer sides of said walls and minimizes gas leakage through the latter.

5. The method of operating an economizer comprising a bank of horizontally disposed tubes connected to provide paths of water flow between the tubes at the top of the bank and the tubes at the bottom of the bank

passing successively through intermediate tubes at different levels, which consists in passing heating gases upward through the inter-tube space of the bank, and passing the water along said paths of flow from the top to the bottom of the bank with a velocity of water flow through the tubes in excess of that permitting equalization of temperature in tubes at different levels by convection currents of the water in the tubes.

6. The combination with a boiler furnace, of means providing an outlet passage for the heating gases issuing from said furnace, a bank of economizer tubes traversing a portion of said passage and a conduit having imperforate walls connected at its ends to said gas passage to form a by-pass about the portion of the latter traversed by the economizer tubes, and a series of dampers distributed along the length of said conduit and each adjustable from an open position into a closed position in which it substantially closes but does not entirely seal the conduit.

7. An economizer comprising a casing provided with an inlet and an outlet for heating gases, and to banks of economizer tubes located therein and providing parallel paths of flow for the heating gases between the inlet and outlet and spaced apart from one another to provide between them a by-pass between said inlet and outlet, and means regulating the flow through said by-pass.

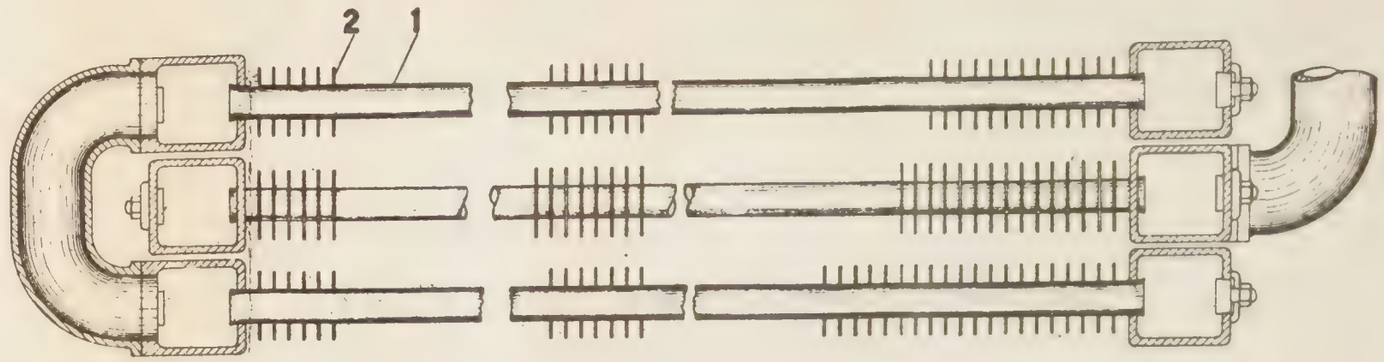
8. The combination of claim 2 further characterized by the arrangement of the tubes in rows transverse to the direction of flow of the heating gases with the tubes in each such row staggered with respect to the tubes in each adjacent row, and with the tubes in the different rows so spaced that the area of the gas path between any two adjacent tubes in adjacent rows is not less than half of the area of the gas path between two adjacent tubes in the same transverse row.

In testimony whereof I hereto affix my signature.

JOHN E. BELL.

Def. Exh. 2
C.A.P.
11-14-27

Fig. 3
Vertical Longitudinal Section of Economizer-Tubes & Headers
on still larger scale



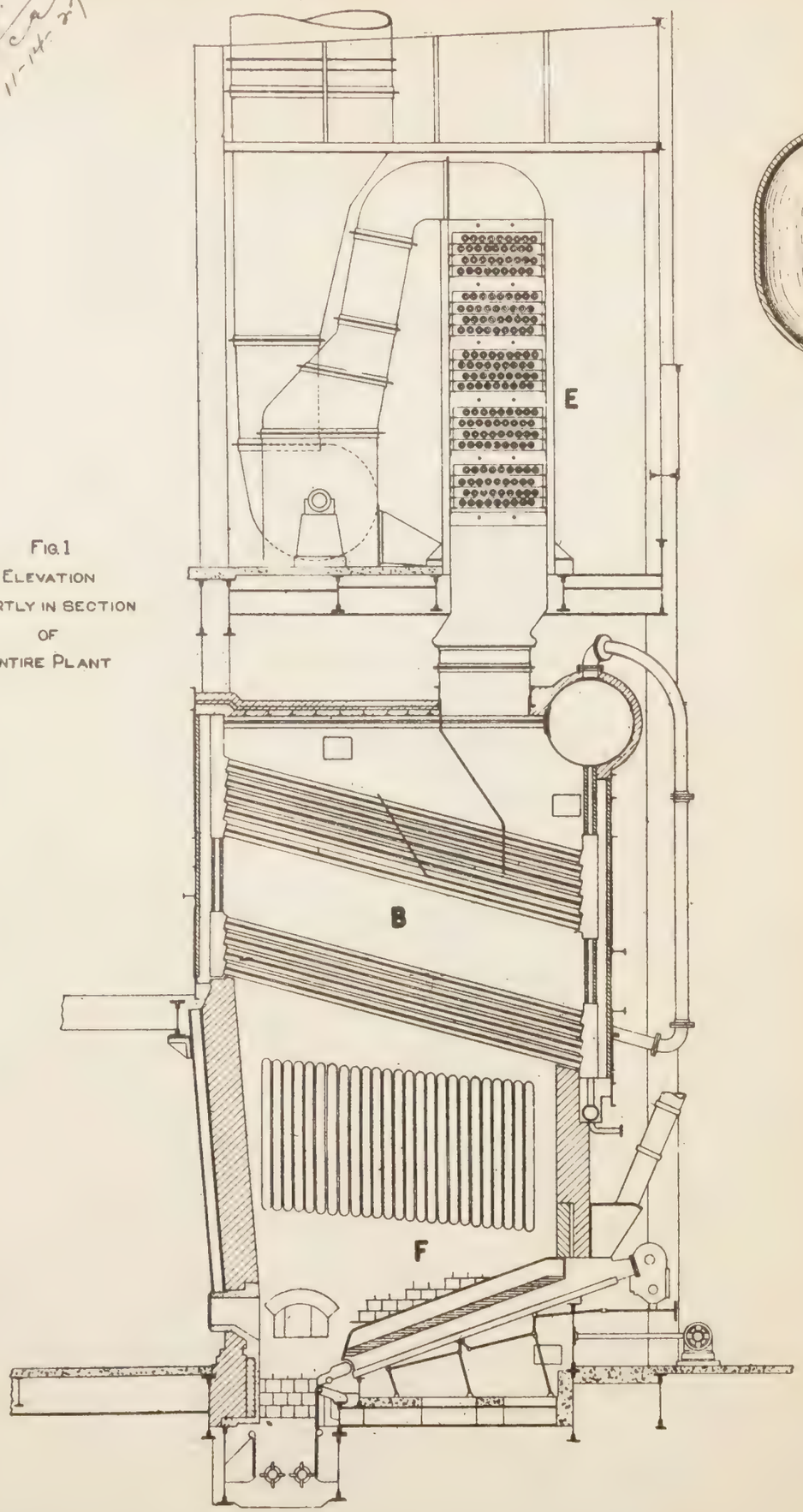


Fig. 1
Elevation
partly in section
of
Entire Plant

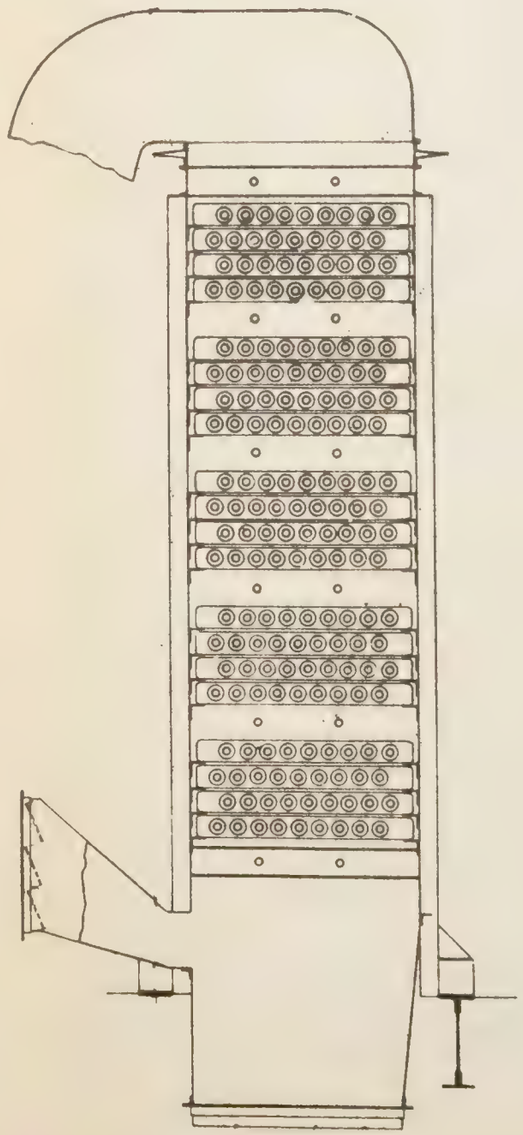


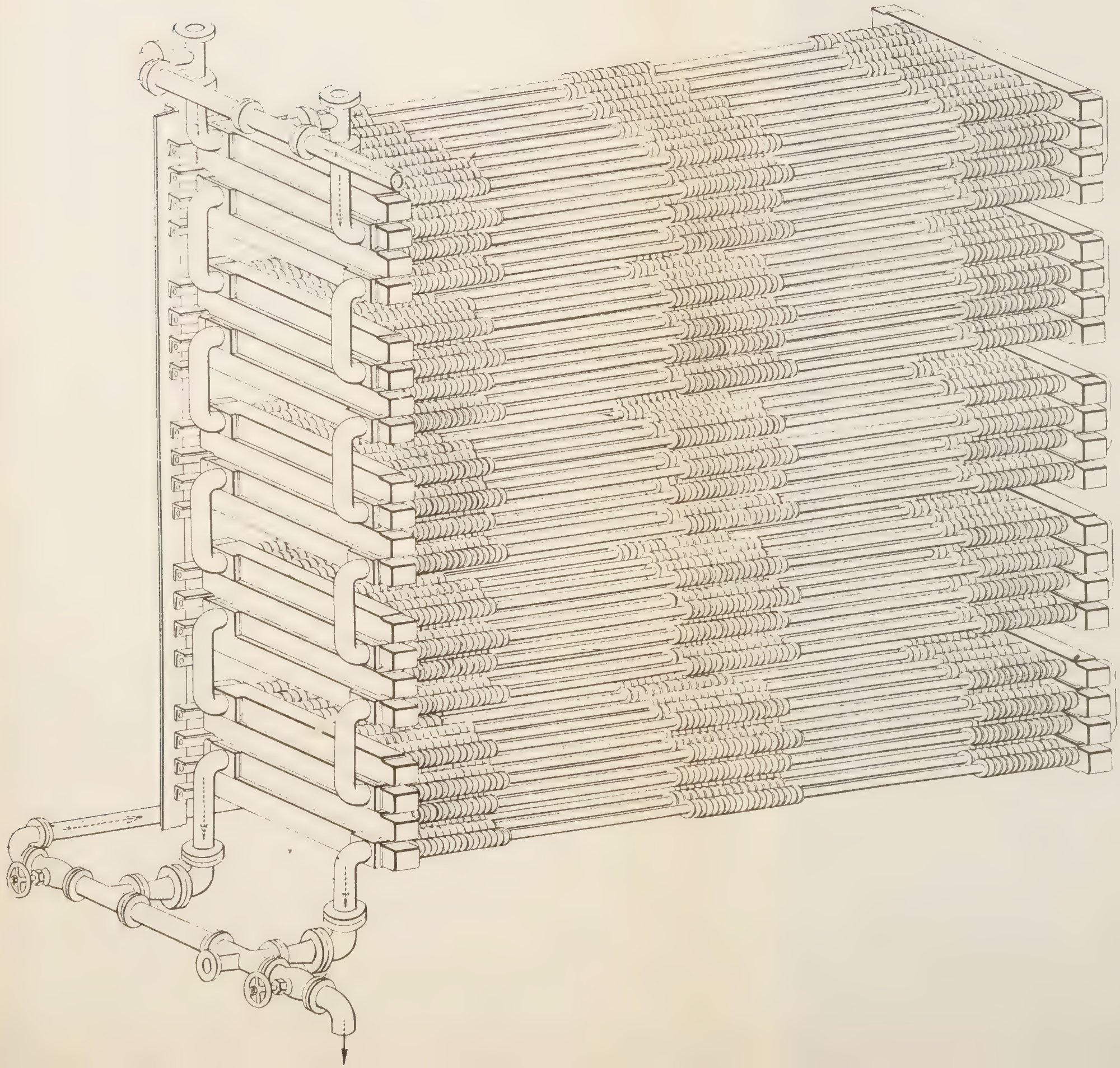
Fig. 2
Vertical Cross Section of Economizer
and Casing
on enlarged scale

PLAINTIFF'S
EXHIBIT 2

PLAINTIFF'S EXHIBIT 2A

FIG. 4

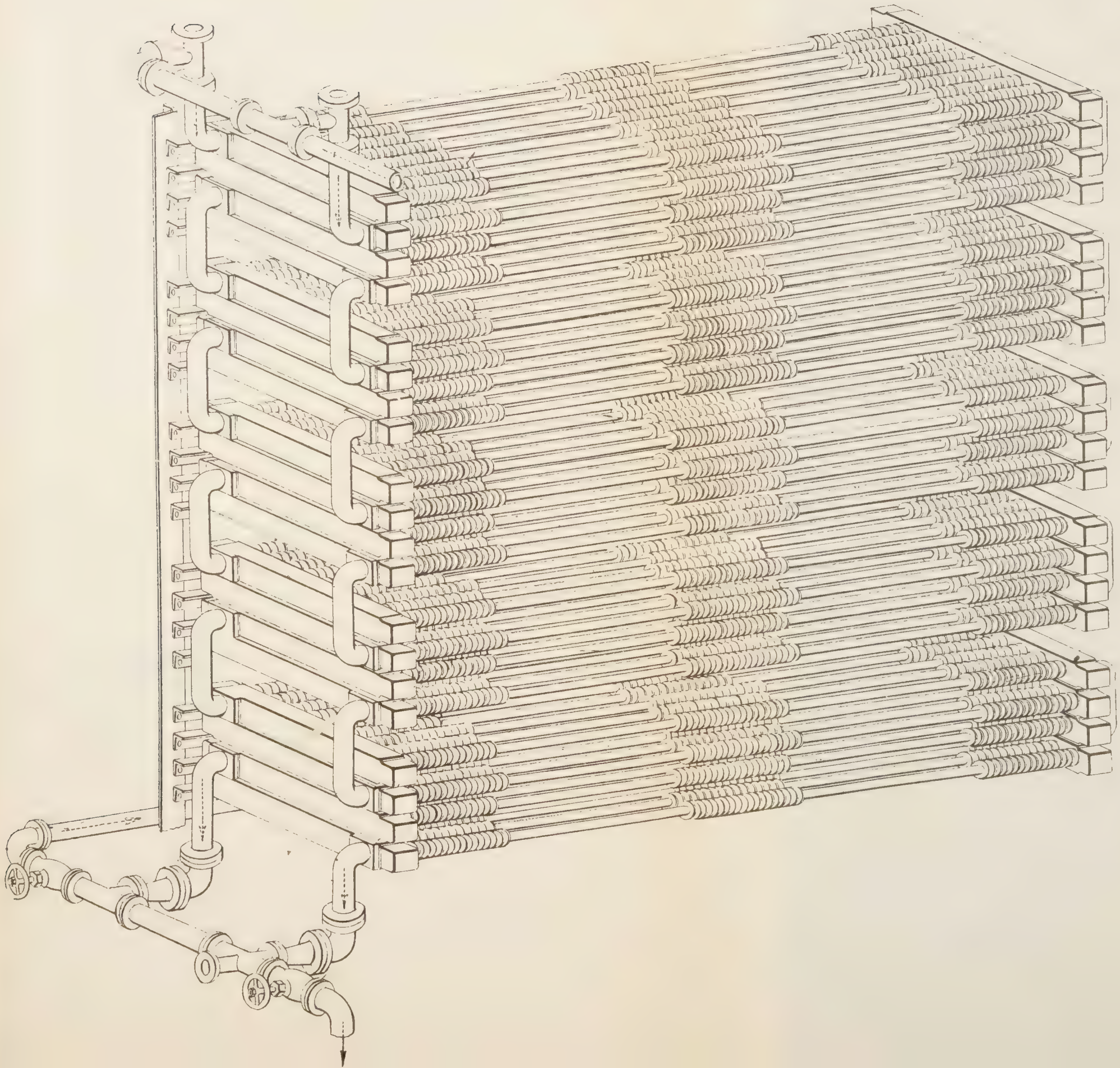
PERSPECTIVE VIEW OF DEFENDANTS ECONOMIZER



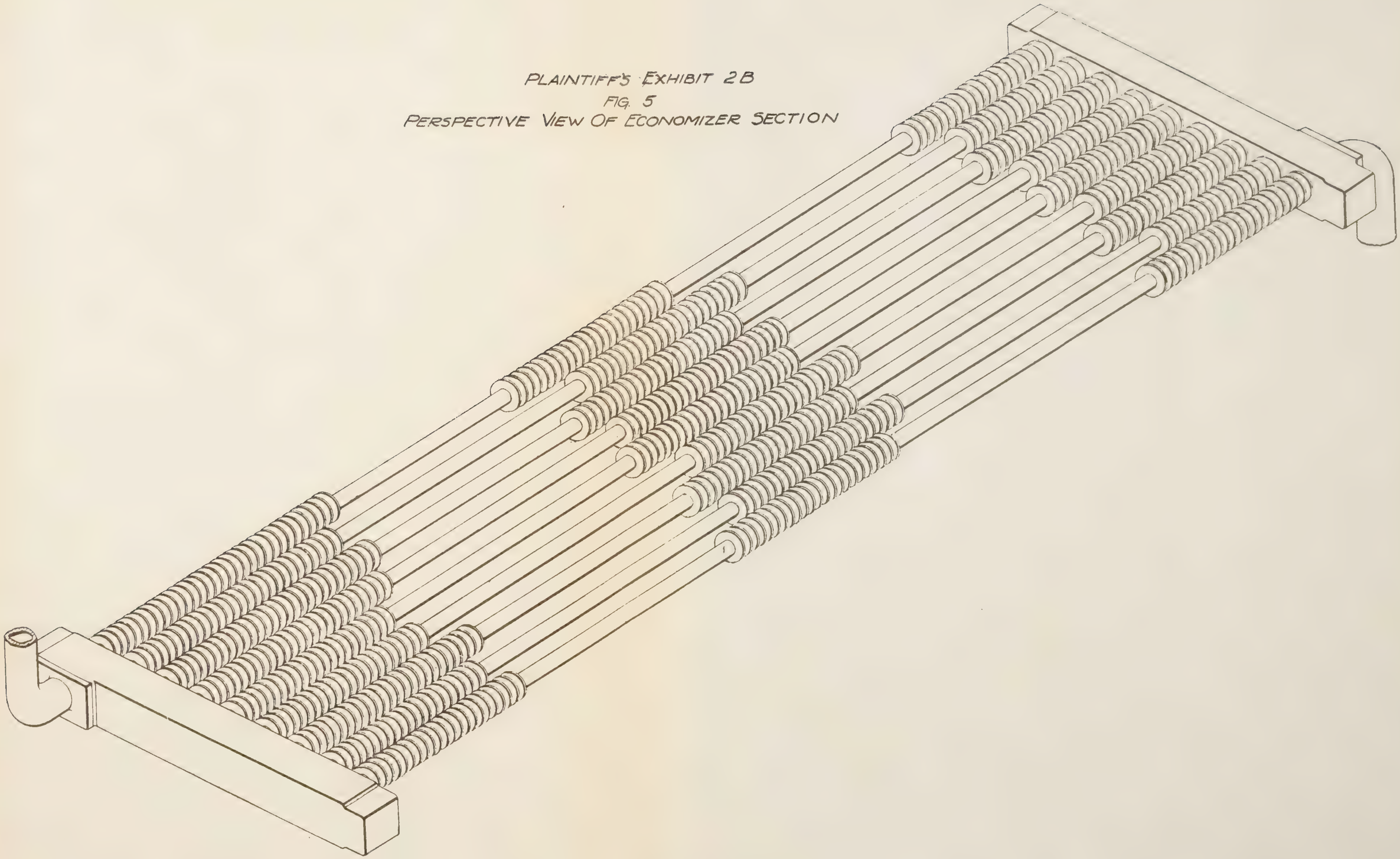
PLAINTIFF'S EXHIBIT 2A

FIG. 4

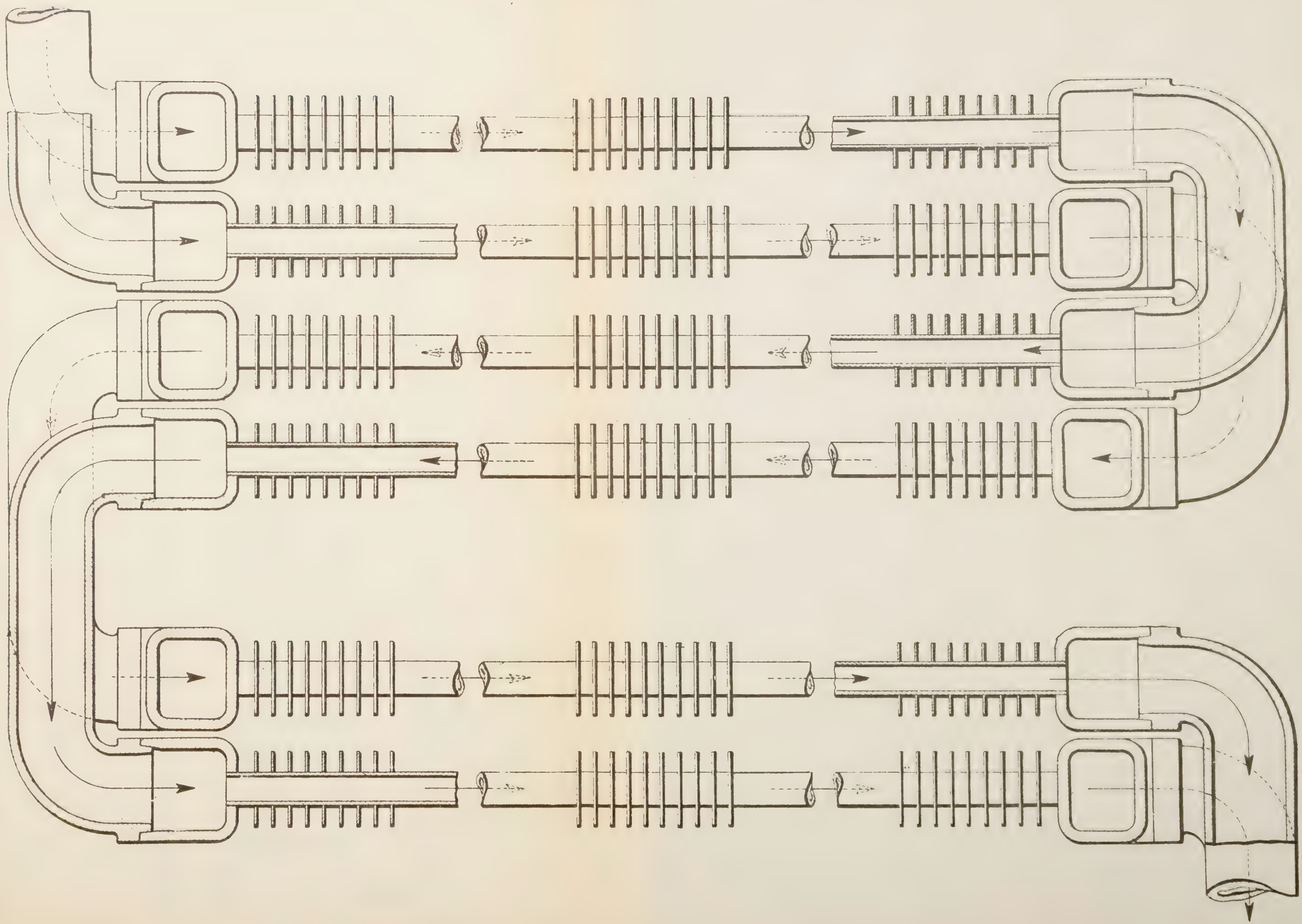
PERSPECTIVE VIEW OF DEFENDANTS ECONOMIZER



PLAINTIFF'S EXHIBIT 2B
FIG. 5
PERSPECTIVE VIEW OF ECONOMIZER SECTION



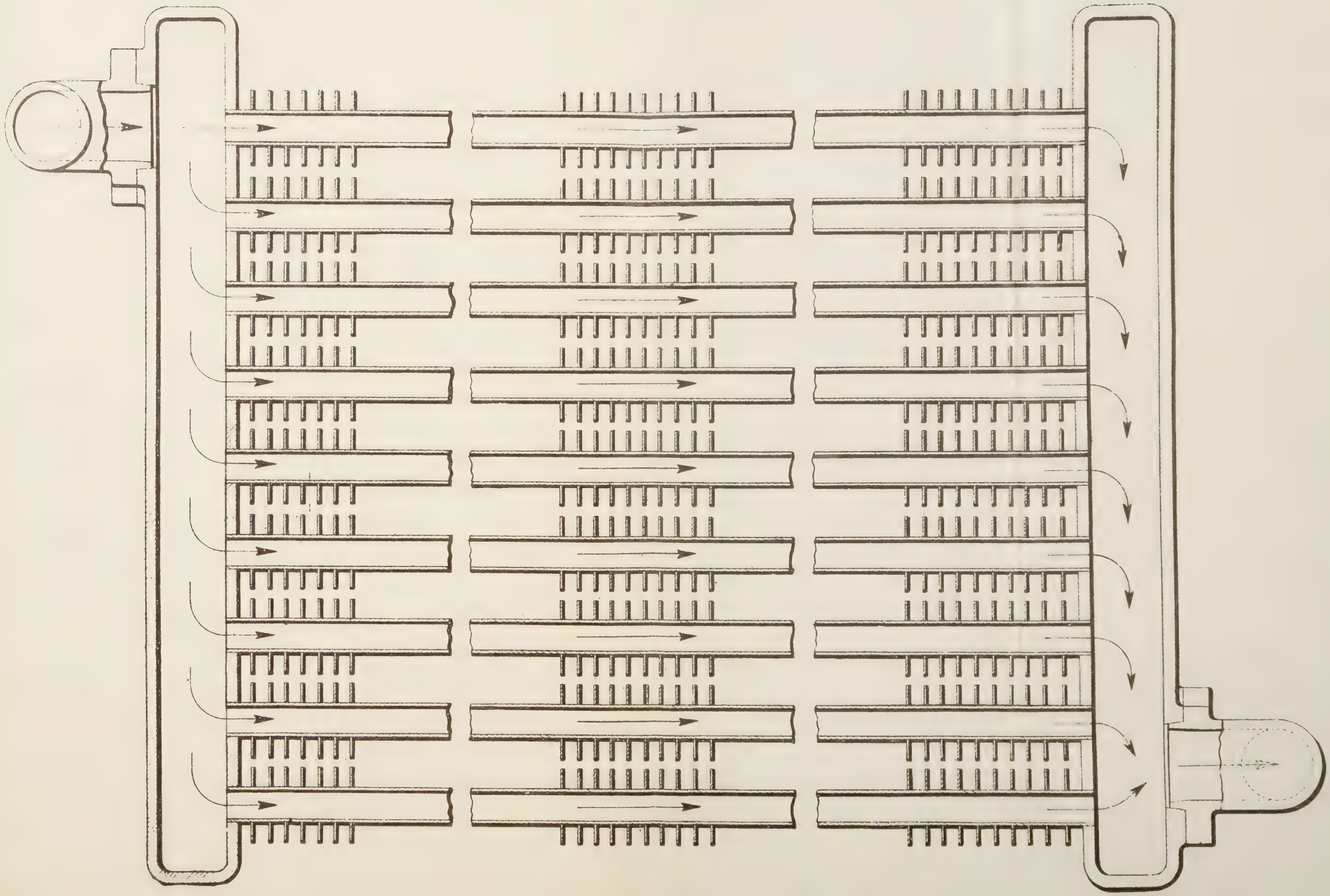
PLAINTIFF'S EXHIBIT 2C
FIG. 6
VERTICAL LONGITUDINAL SECTION OF
ECONOMIZER TUBES AND HEADERS



PLAINTIFF'S EXHIBIT 2 D

FIG. 7

HORIZONTAL SECTION OF TUBES AND HEADERS



PLAINTIFF'S EXHIBIT 3.

File Copy 583

WED/AK January 27, 1926.

Connecticut Light & Power Co., Waterbury, Connecticut.

Gentlemen: We are informed that you have purchased, and are about to install, or to have installed in your plant at Devon, Connecticut, economizers constructed by the B. F. Sturtevant Company and of the type employing gilled tubes.

We believe the type of economizer with gilled tubes which the B. F. Steurtevant Company is now making and selling is an infringement of our U. S. Patent No. 1,565,305, granted December 15, 1925, and that installations of such economizers may also involve infringement of our U. S. Patent No. 1,565,304, granted December 15, 1925. 584

We assume that you already have knowledge of our above mentioned patents, as we brought those patents to the attention of the United Gas Improvement Company of Philadelphia some weeks ago in connection with the proposed purchase of economizers for your Devon plant, but to avoid any possible failure on your part to understand the situation, we now formally warn you against infringing either of the above mentioned patents, and warn you that we intend to take all necessary and proper steps to enforce our rights against makers and users of economizers which infringe upon our patent rights. 585

Yours very truly,

POWER SPECIALTY COMPANY

c.c. Phila. Secretary.

2 copies to Mr. Hubbell

Sturtevant

(REG. U. S. PAT. OFF.)

Lead Coated Extended Surface TYPE Y ECONOMIZER

BULLETIN No. 334

B. F. STURTEVANT COMPANY
HYDE PARK, BOSTON, MASS.

Printed in the U. S. A.

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Principle of Sturtevant Economizer

THE Sturtevant Economizers are designed to recover a large part of the waste heat that is usually lost up the chimney. The hot waste gases, which leave the boiler and escape to the chimney, are led around and between a series of pipes through which the feed water is passed on its way to the boiler. The feed water absorbs a large part of the heat otherwise wasted, and the boiler is supplied with water at a higher temperature.

WHAT THE STURTEVANT ECONOMIZER DOES

Saves Fuel: It saves fuel by increasing the temperature of the feed water.

Increases Boiler Capacity: Since it supplies feed water at this high temperature, less work is required to vaporize the water, which increases the boiler capacity.

Reduces Repairs: It reduces the fluctuations in feed-water temperatures and thus reduces the strains caused by expansion and contraction, which increases the life of the boiler.

Reduces Smoke and Soot: It reduces smoke and soot as the hot gases deposit a large amount of soot on the colder surface of the economizer pipes from which it is blown and collected in a soot chamber.

Reservoir of Hot Water: It provides a large reservoir of hot water, which aids the boilers in meeting sudden demands for steam in textile mills, paper mills, and many other industrial plants using steam or hot water in process work.

All These Savings are Secured from Otherwise Wasted Heat

DEVELOPMENT OF STURTEVANT ECONOMIZERS

Economizers have been used abroad and in this country for many years, but the use of economizers is receiving more attention today than during any previous period. The present interest in economizers is the natural result of four factors —

First: Coal has increased in price to the point where it is necessary to obtain maximum fuel efficiency.

Second: Higher capacities are demanded from the boilers, resulting in a higher exit gas temperature. Obviously, the greater the difference between this temperature and the entering water temperature, the greater the saving accomplished by the use of economizers.

Third: Boiler pressures have been steadily rising, which causes an increase in the exit gas temperature.

Fourth: The recovery of the heat formerly wasted up the stack offers the biggest opportunity for saving in a power plant.

USE OF ECONOMIZERS

The cast-iron Sturtevant Economizer (Figure 1) is well known and needs but little description in this pamphlet. Cast-iron tubes approximately four inches in diameter are pressed into cast-iron headers. These sections are then assembled vertically, so that the water either flows by natural circulation from the bottom of the machine to the top, or in forced circulation in groups of four or eight sections. In this design, the gases flow horizontally. Later designs have the tubes arranged horizontally with horizontal gas flow. A very compact design that we have used allows the economizer to be set in the rear of a boiler unit with headers and tubes placed horizontally and with the gas flowing vertically.

In early practice, it was the custom to use one economizer for a group of boilers. Present practice leans toward the use of individual economizers. In the latter case, there is a minimum of air leakage. This tends to increase the efficiency of the economizer and lightens the load on the induced draft fan. In early practice, it was the custom to have smaller boilers and plenty of them, so that individual economizers would have been uneconomical. Nowadays, with properly designed apparatus, there should be no necessity to shut down a boiler-economizer unit, except when it is out for cleaning.

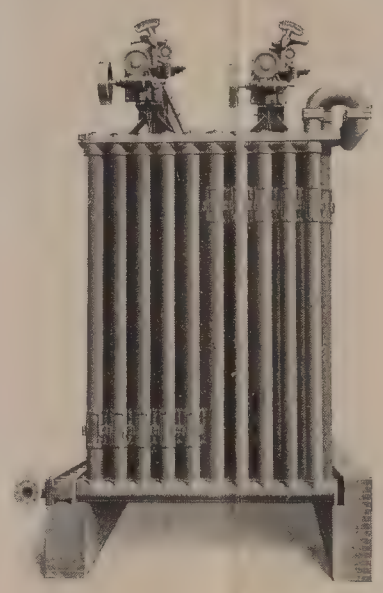


Figure 1
Cast-Iron Economizer

In the individual system, it is possible to obtain a higher over-all efficiency over a wide range of operation. As the boiler output increases, the amount of gas is increased, its temperature is higher, and the waste gas gives up more heat to the water. This holds true for a battery of two boilers, where it is found advisable to install one economizer for two boilers on account of space conditions.

STEEL TUBE ECONOMIZER

Our experience has proven to us that corrosion was practically unknown when cast-iron economizers were installed in the group system. However, after individual economizers had been in operation long enough for us to study them, we found very definite signs of corrosion. We concluded, naturally, that in the group system the gas was flowing through the machine most of the time and the water was nearly always at a temperature above the dew point of sulphuric acid. On the other hand, when individual machines were taken out of service during the period of boiler repairs and cleaning, the soot remaining on the pipes absorbed moisture and started a corrosive action.

This study caused us to go very slowly in our development of a steel tube economizer. We realized pressures were mounting, and that a steel tube machine would be in great demand; but our experiments proved conclusively that the steel must be protected against both outside corrosion caused by the gases, and inside corrosion due to the oxygen found in the water. External

corrosion is governed by the temperature of the economizer surface, and in unprotected steel tube economizers it is necessary to bring the feed water to the machine at a temperature well above the dew point. Corrosion is very rapid if condensation takes place with coal having a high sulphur content, as the sulphur-laden gases readily form sulphuric acid. Even with a low sulphur content, it is found inadvisable to bring the feed water in at a temperature less than 160° F, but at this temperature the dissolved oxygen in the water is very high unless expensive de-aërators are used.

When the water is between 100° and 200° it is very actively corrosive and severe pitting will result. Outside and inside corrosion were so severe in the older designs of steel tube economizers that for some time they were considered impracticable. It is generally agreed that anything in excess of .2 of a c.c. of oxygen per litre of water is fatal to the old design of steel economizers unless protected against this corrosive action. To obtain the elimination of this air, it has been necessary to use expensive de-aërators or else heat the water up to 210° F. It is difficult, however, to maintain this temperature except as an average, and the variation in temperature might be from 170° to 250°. The lower temperature enables the water to carry a large amount of oxygen and cause corrosion.

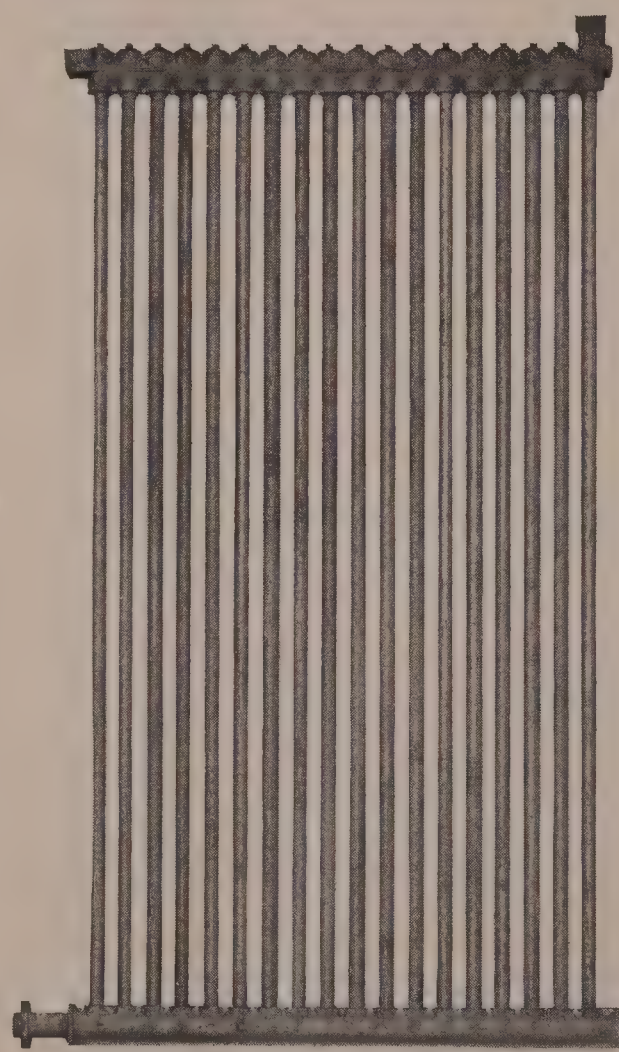


Fig 2. Type "X"

THE LEAD-COATED IDEA

Having a clear knowledge of these conditions, we started a series of experiments to determine the best means of protecting steel surfaces. These experiments were carried on over several years, and finally led to a successful conclusion when we developed a patented process of lead coating. We found that a lead alloy applied in a new way solved the problem of outside and inside corrosion. Several machines were built and installed and have fully lived up to our expectations. They were known as our type "X" (Figure 2). The design was similar to our cast-iron type, except that the tubes were reduced to 2½″ outside diameter. The reason for the larger tubes in the cast-iron machine was that scrapers were used to clean them, and four inches was about as small a pipe as could be cleaned with these scrapers. Soot blowers have since been found so satisfactory for cleaning economizers that we decided to reduce the size of the pipe, to provide smaller paths for the passage of the gases.

DEVELOPMENT OF THE TYPE "Y" EXTENDED SURFACE

The type "X" economizer, lead coated, was so successful that we completed the plan, which we had been working on for several years, of bringing out an extended-surface machine. The value of an extended surface had been recognized for a long time for installations where there was but little room available for the economizer. Our earlier experiments showed that it was necessary to get an absolutely tight joint between the extended-surface discs and the pipe. We had tried heating steel and cast-iron discs and shrinking them on steel tubes, but without success. The best we could get was an efficiency of about 70 per cent for the extended surface, where other apparatus which we build with extended surface showed very much higher results.

This scheme was abandoned, and, after a long period of experimenting, we finally secured a method which has been patented for putting steel discs on a pipe so tightly that an indentation appears on the pipe under every disc (Figure 3). Our tests now showed the heat transfer we had a right to expect, which proved that to get the best results the contact between disc and pipe must be absolutely tight. The pipes with the discs assembled are lead coated and then expanded into headers of forged or cast steel.

Fig. 3. Pipe Assembly

Fig. 4. Type "Y" Section

DESIGN

Sections:

The type "Y" design is much simpler than any of our others and many parts have been eliminated, which naturally reduces the number of joints to the minimum. Each section (Figure 4) is completely assembled and tested at our Works and shipped as a unit. This is a particularly desirable feature, as it means that the erection can be completed very quickly. Pipes are rolled into the headers as in boiler construction. The front header has a partition in the center, and the path of the water is toward the rear of the section for half the number of pipes, then forward to the front header in the remainder of the pipes. A 180° bend connects one section to the one above. All these connections are on the front of the machine where it is easy to get at them by simply opening the doors, as shown by the photograph, Figure 6.

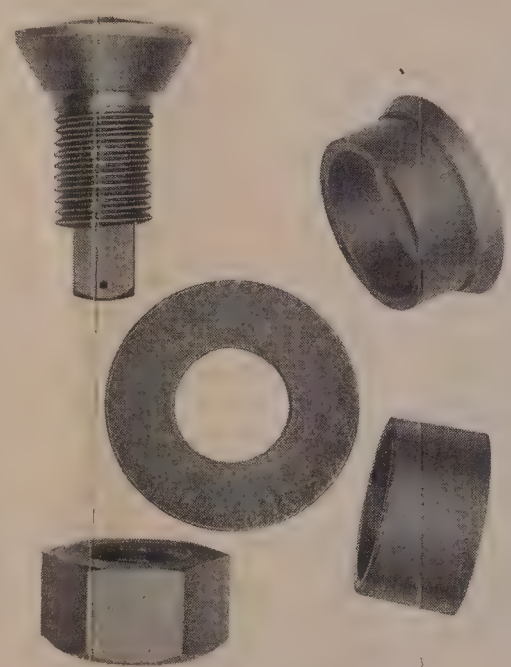


Fig. 5. Cap Assembly

Holes in the headers opposite the pipes are provided for rolling the tubes, inspection and cleaning. These are closed by means of the cap shown in Figure 5. The cap is inserted from the outside, after which the straight copper gasket is put in place, and then the washer and nut put on. When the nut is screwed up it pulls the gasket against the washer and then forces it out against the inside edge of the hole. The pressure inside of the header only makes the cap tighter. Figure 4 does not show this type of cap but does show a tapered cap which is sometimes used. In this case the cap is inserted in the large hole and pulled into place. Either type of cap can be used according to the wish of the buyer.

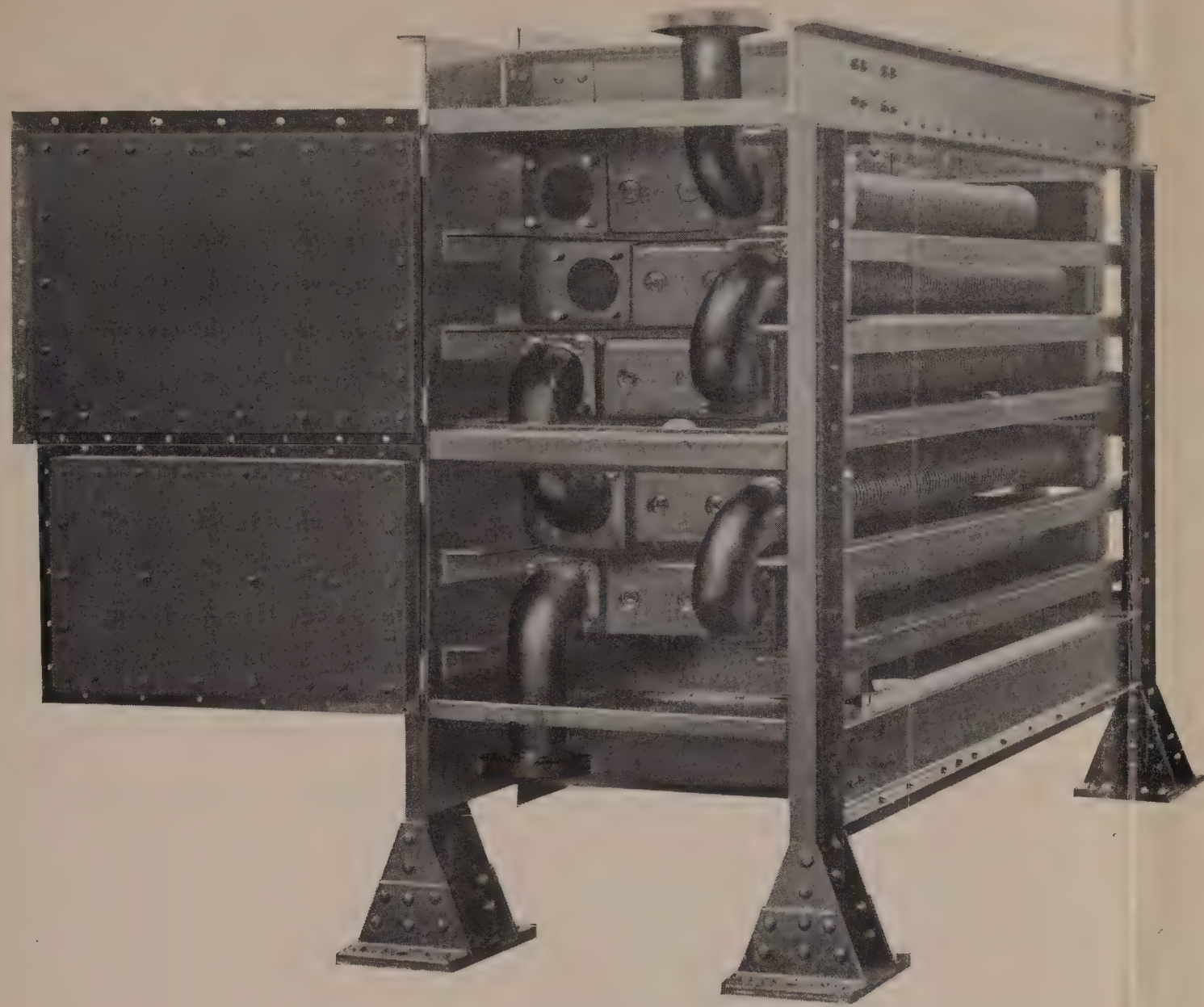


Fig. 6. Front View showing Water Connection

Supports:

Figure 6 clearly shows the method of supporting the sections. The headers rest on angles which in turn are carried by the corner columns. With long sections, we use intermediate columns on the sides which carry the supporting angles at their centers. We also support long pipes at their centers by means of a channel section. This support rests on the same angles that support the headers and is withdrawn with the section. By supporting each section independently on angles we have an arrangement which permits repairs with a minimum delay and expense. It is only necessary to remove two bends in front and draw out the section without disturbing the adjacent ones. A spare section is kept on hand which can be slipped in place and the other repaired when convenient. Frames are provided as shown at top and bottom for flue connections.

Soot Blowers:

Between every group of six sections a space is left for soot-blower elements. The soot blowers go in through the back of the machine. Each element blows

over not more than three sections. The spacing of the elements horizontally depends on the number of pipes per section.

Casing and Insulation:

Every precaution has been taken to insure tightness of the machine and the maximum heat insulation.

On the front of the machine we provide doors filled with 2″ insulating material. The fixed panel between doors is also insulated. Provision is made in the construction of doors and panels for double sealing. This is shown clearly in Figure 6. The door is sealed by the plate at the back of the fixed panel and by the front plate of the door itself. As a further precaution we provide asbestos gaskets and fasten the door tightly by means of stud bolts and nuts on all four sides. At the back of the machine we use insulated sectional covers, taking the same care to have all joints tight.

The side covering consists first of a steel plate or panel next to the supporting angles (Figure 7). This plate extends back of the channel column itself, forming a lap joint. It extends along the top and bottom inside of the flue frame channels, forming a lap joint at these points also. Thus the plate itself makes the sides practically air tight. Next to the steel plate panels we put a layer of 2½″ insulating material and on the top of this another steel plate which is bolted through to the inner plate.

The outside plate is flanged around its edges and is bolted to the channel flanges. This side covering is made in this way so that it will be kept in place permanently; consequently it is divided into as few panels as possible. At no place is there a butt joint extending through the covering. Generous laps are provided along all the edges and at the same time provision is made for expansion.

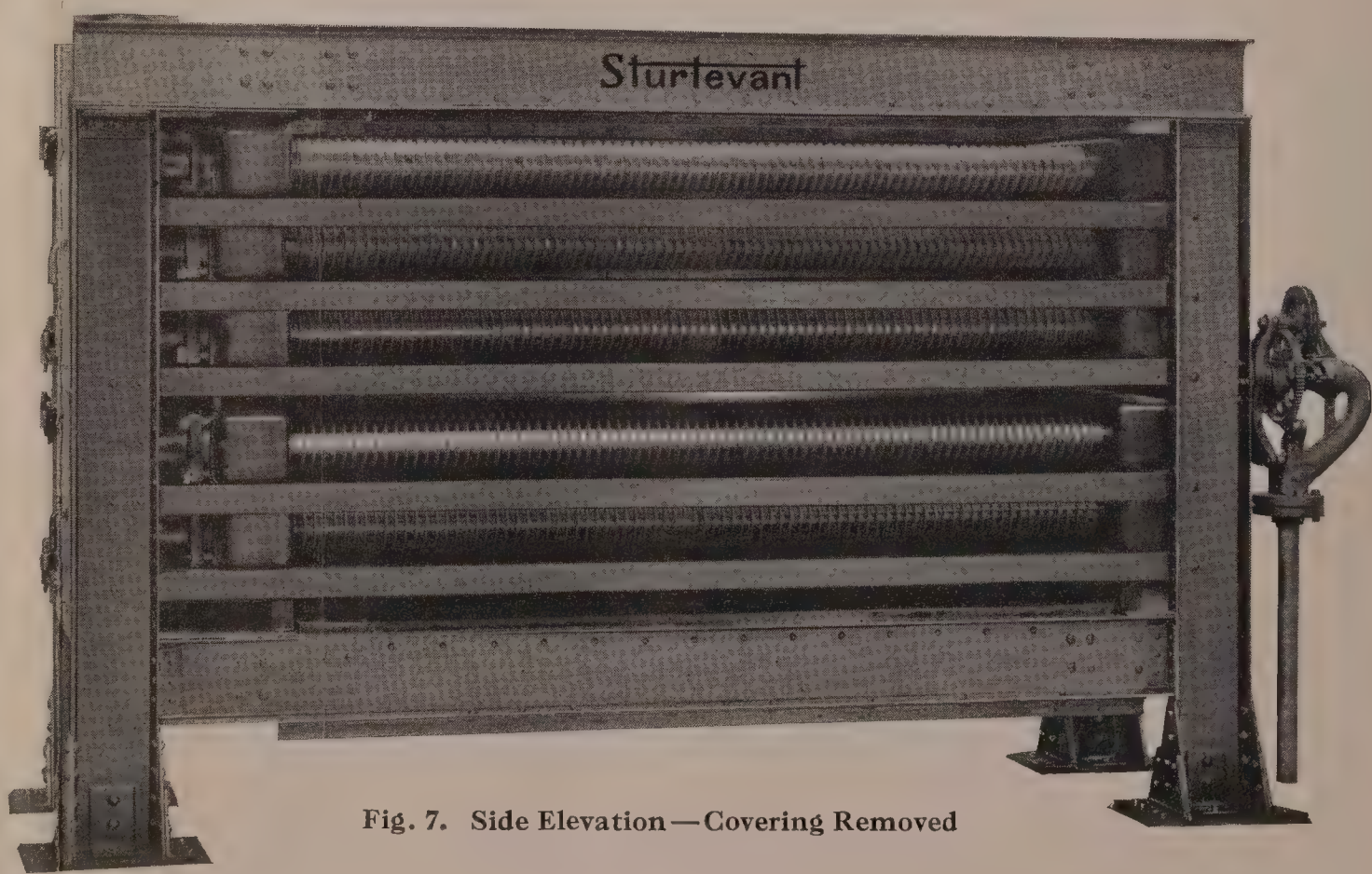


Fig. 7. Side Elevation—Covering Removed

The channel columns and the flue frame on the gas inlet side are insulated as well as the sides. We use a very high-grade efficient insulation on the sides and doors and also pack the spaces between the headers with insulating material.

Circulation:

Water: The circulation is contra-flow. All the water passing either up or down goes through each section as explained under Sections, page 6. Alternate ends of headers are connected together by 180° bends and the water passes from one section to the next one through these bends. The feed-water connections pass through the square holes in the top and bottom at the front of the machine. Cover plates, which fit snugly around the connections, are used to seal the openings. There are never more than two of these holes in the top or bottom. The flow of water is kept well above turbulence in order to wipe away the film next to the pipe and also to prevent scaling. High-velocity water is now well recognized as essential in economizer design both here and abroad.

Scaling does not take place in a turbulent flow, but is rapid in the case of the velocity below the critical point. It has also been proven that within the limits of turbulent flow air bubbles are swept away. These points have been studied and a velocity through the machine has been established that insures maximum heat transfer without increasing the pressure drop to any appreciable extent. It is best for the water to flow upward, but this is sometimes difficult to arrange. High and low points are avoided and proper precautions are taken to prevent pockets of gas, vapor or mud. The best economizer is one in which the water is heated gradually and this is primarily a question of circulation. The water reaches a much higher temperature than when there is a mixed circulation or unequal temperature.

Gas: The gas passages are always staggered. The discs cause a great impinging action which naturally increases the heat transfer. The velocity of the gases has been increased to the point where the soot is wiped away by the violent scrubbing action nearly as fast as formed. The little soot remaining is easily cleaned from the smooth lead surfaces by the soot blowers. The benefit of high heat transfers, resulting from high velocities, has long been known in waste-heat boilers. However, high velocities mean an increase in resistance through the machine, and care must be taken not to exceed the economic limit of draft loss.

Friction Loss:

An economizer has to be proportioned to meet each individual case. There is a point above which the velocity of the gas should not be increased, as the increased heat transfer would be counter-balanced by the additional power required for the fan. This additional power must be capitalized. It cannot be sold and is a net deduction from the output of the plant. As manufacturers of fans, and of the motors, turbines, or engines to drive them, we are able to study this problem as a whole, and give unbiased opinions as to the proper equipment. Furthermore, we have the advantage of assuming "undivided responsibility" for the operation of this equipment.

After the proper velocity is fixed, the next step is to determine the proper amount of heating surface, which is limited by the frictional resistance and the final temperature of the water. Each section increases the temperature of the water but at diminishing rates, and a point is reached where the increased return does not warrant the investment. This point is primarily determined by the cost of the equipment and also the cost of the fuel and the number of hours in operation.

Another determining factor is the boiler pressure which establishes the temperature of water to the boiler. Good practice provides that the temperature of the feed water from the economizer should not be within 50° of the temperature of the steam. This prevents the possibility of the feed water forming steam in the economizer while under the control of the feed-water regulators.

Valves:

Two relief valves and one blow-off valve of approved make are furnished with each economizer.

Fig. 8. Test and Assembly

Tests:

We have an extensive test department in charge of competent and careful inspectors. Headers are tested up to 1000 lbs. hydrostatic pressure with *hot water* after machining. Each section is tested to approximately twice the operating pressure before it is allowed to leave the plant. Sections are shipped completely assembled and are installed in their supports as soon as received at the plant, thus insuring a minimum amount of time for erection. After erection, the complete machine is again tested, which insures against any possibility of leaks in headers, caps, or joints.

ADVANTAGES OF ECONOMIZER INSTALLATIONS

Fuel Saving: The saving due to an economizer may be easily found or estimated from the equation

$$\text{Saving in per cent} = \frac{T - t}{H - h} \times 100$$

Where T = Temperature water entering boilers.
t = Temperature water entering economizer.
H = Total heat in steam.
h = Total heat in water entering economizer.

It is commonly stated that 1 per cent saving in fuel is obtained for every 11 degrees rise in feed water. This is gross saving and from this should be subtracted the fixed charges, and also the cost of operating the induced draft fans that is directly traceable to the economizer, which in a properly designed installation, usually amounts to a fraction of 1 per cent. It must also be remembered that an economizer reduces the volume of gases, hence permits the use of a smaller fan.

INCREASE IN BOILER CAPACITY

One of the most discussed questions today in power-plant circles is that of the limits in boiler-heating surface per foot of width, and whether or not additional surface should be added to the boiler or economizer. We have witnessed a period in which the number of tubes high in a boiler have been increased so as to give a very large heating surface, making the use of economizers unnecessary. This theory seems to have run its course, and in many cases the power stations originally installing these high boilers have gone back to the boiler-economizer units. In fact, the pendulum seems to have swung in the opposite direction, for there is now much experimenting being done with reduced boiler-heating surface using one-pass boilers and the required amounts of economizer surface. It is hard to forecast the future, but it is probable that a middle course will be adopted, using moderate amounts of boiler-heating surface and the proper amount of economizer surface to give the best return over the entire year's operation.

ENGINEERING SERVICE

This Company manufactures both cast-iron and steel-tube economizers, air heaters, and forced and induced draft fans, as well as the motors, steam turbines, or engines that operate them. *First*, we assume undivided responsibility for the operation of this part of your plant — a great advantage when you need service. You deal with one company instead of a number. *Second*, we can advise you without prejudice as to whether you should use economizers, air heaters, or both; and also as to the proper fan equipment. We maintain six large plants in various parts of the country and a large corps of engineers located in all the principal cities, so that we are splendidly equipped to give you prompt, efficient service and co-operation.

Sturtevant
(REG. U.S. PAT. OFF.)

B. F. Sturtevant Company

Main Office and Works: Hyde Park, Boston, Mass.

Plants

Hyde Park, Mass. Framingham, Mass. Camden, N. J. Sturtevant, Wis.
Berkeley, Calif. Galt, Ontario

Sales Engineering Offices

Atlanta, Ga.
501–2 Glenn Building
Cor. Marietta and Spring Sts.

Boston, Mass.
60 State Street

Buffalo, N. Y.
700 Crescent Avenue

Camden, N. J.
Thorne and Copewood Sts.

Charlotte, N. C.
1107 Queens Road

Chicago, Ill.
1042 Wrigley Building
410 No. Michigan Avenue
Sales Headquarters — Western Division

Cincinnati, O.
918 Provident Bank Building

Cleveland, O.
1603 St. Clair Avenue

Dallas, Texas
517 Mercantile Building
810 Main Street

Denver, Colo.
314 Tramway Bldg.

Detroit, Mich.
3000 Grand River Avenue

Hartford, Conn.
621 United States Security Trust Co. Bldg.

Indianapolis, Ind.
1101 New City Trust Bldg.
108–110 East Washington St.

Kansas City, Mo.
423 Dwight Building
1004 Baltimore Ave.

Los Angeles, Calif.
511 Hollingsworth Building
606 So. Hill Street

Minneapolis, Minn.
1024 Metropolitan Life Bldg.
Cor. Second Ave. and S. 3rd St.

New York, N. Y.
Graybar Bldg.
420 Lexington Ave.

Pittsburgh, Pa.
711 Park Building
355 Fifth Avenue

Portland, Oregon
608 Lewis Bldg.

Rochester, N. Y.
212 Cutler Building
42 East Avenue

St. Louis, Mo.
2086 Railway Exchange Bldg.
611 Olive Street

Salt Lake City, Utah
803 McIntyre Building
68 South Main Street

San Francisco, Calif.
757 Monadnock Building
681 Market Street

Seattle, Wash.
956 White-Henry-Stuart Bldg.
Fourth Ave. and Union Street

Washington, D. C.
1006 Loan and Trust Building
900 F Street, N. W.

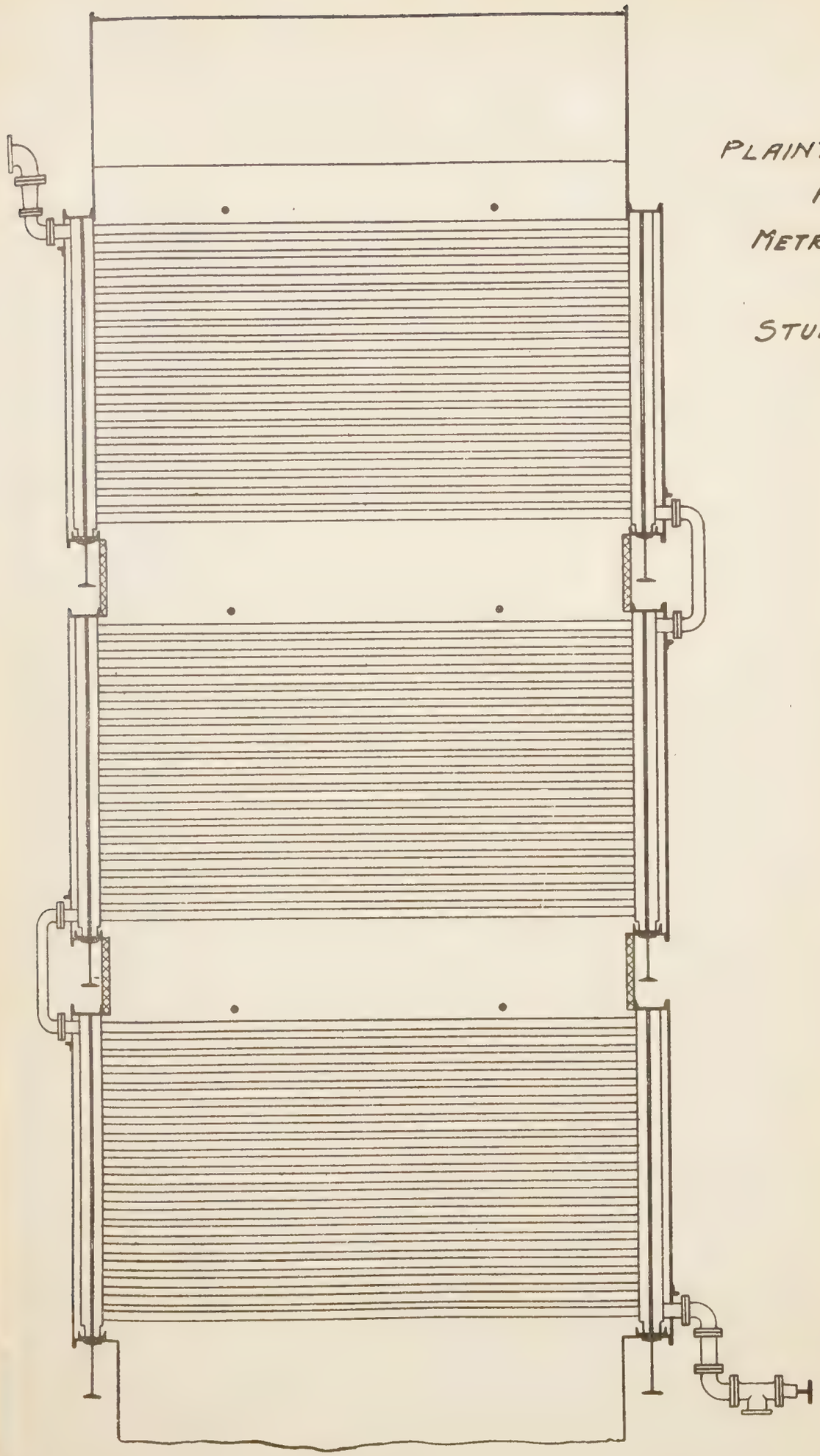
Montreal
553 New Birks Building
10 Cathcart Street

Toronto
1010 Lumsden Building
6 Adelaide Street, East

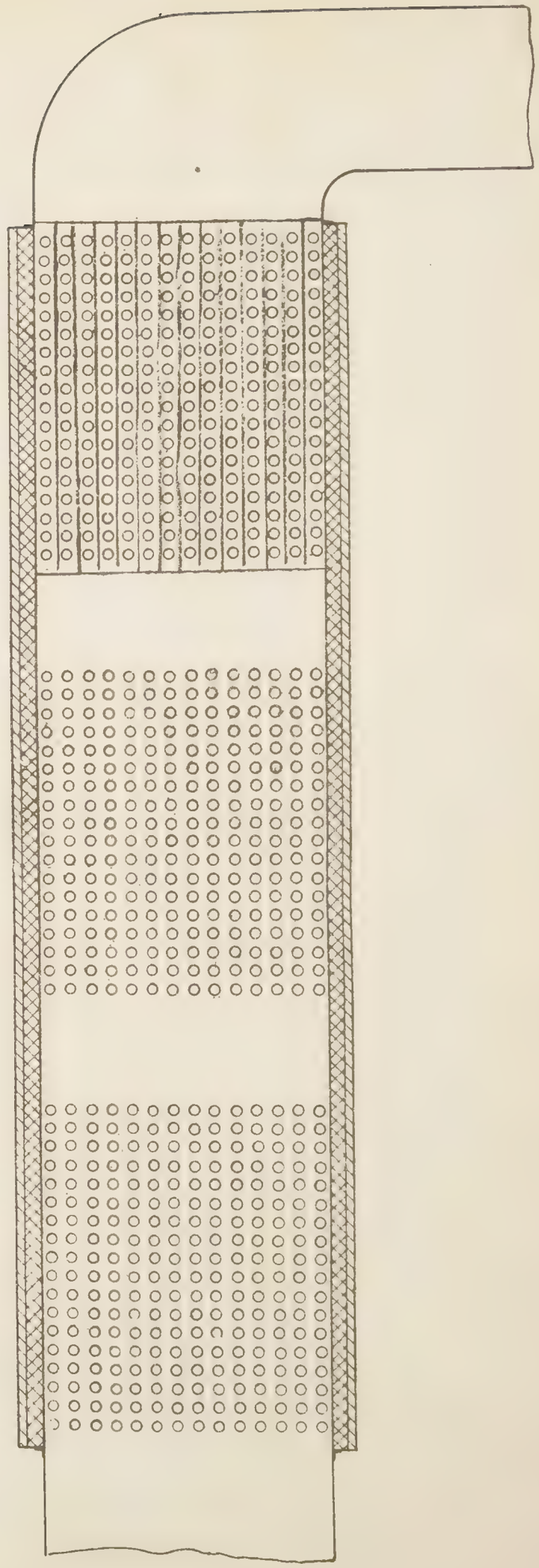
Foreign Representatives

American Trading Co.
1 Itchome, Yuraku-Cho, Kojimachi-Ku, Tokyo, Japan
American Trading Co. . . . . 3 Canton Road, Shanghai, China
Ernshaws Docks & Honolulu Iron Works . . . . . Manila, P. I.
H. P. Gregory & Co., Ltd. . . 74 Clarence St., Sydney, N. S. W.
Blair, Reed & Co., Ltd. . . . . Nathans Bldg., Wellington, N. Z.
International Gen. Elec. Co., Inc.
Apartado 139, Caracas, Venezuela
International Gen. Elec. Co., Inc.
Apartado 1055, Bogota, Colombia
General Machinery and Supply Co.
Apartado 258, Tampico, Mexico
Pedro Martinto Inc. . . . . San Jose 399, Lima, Peru
A. E. Barker, 259–261 Commissioner St., Johannesburg, So. Africa
Honolulu Iron Works . . . . . Honolulu, T. H.

Sturtevant
(REG. U.S. PAT. OFF.)



PLAINTIFF'S EXHIBIT Nº 5
KEENAN DRAWING
METROPOLITAN POWER COMPANY
MIDDLETOWN, PA
STURTEVANT ECONOMIZER



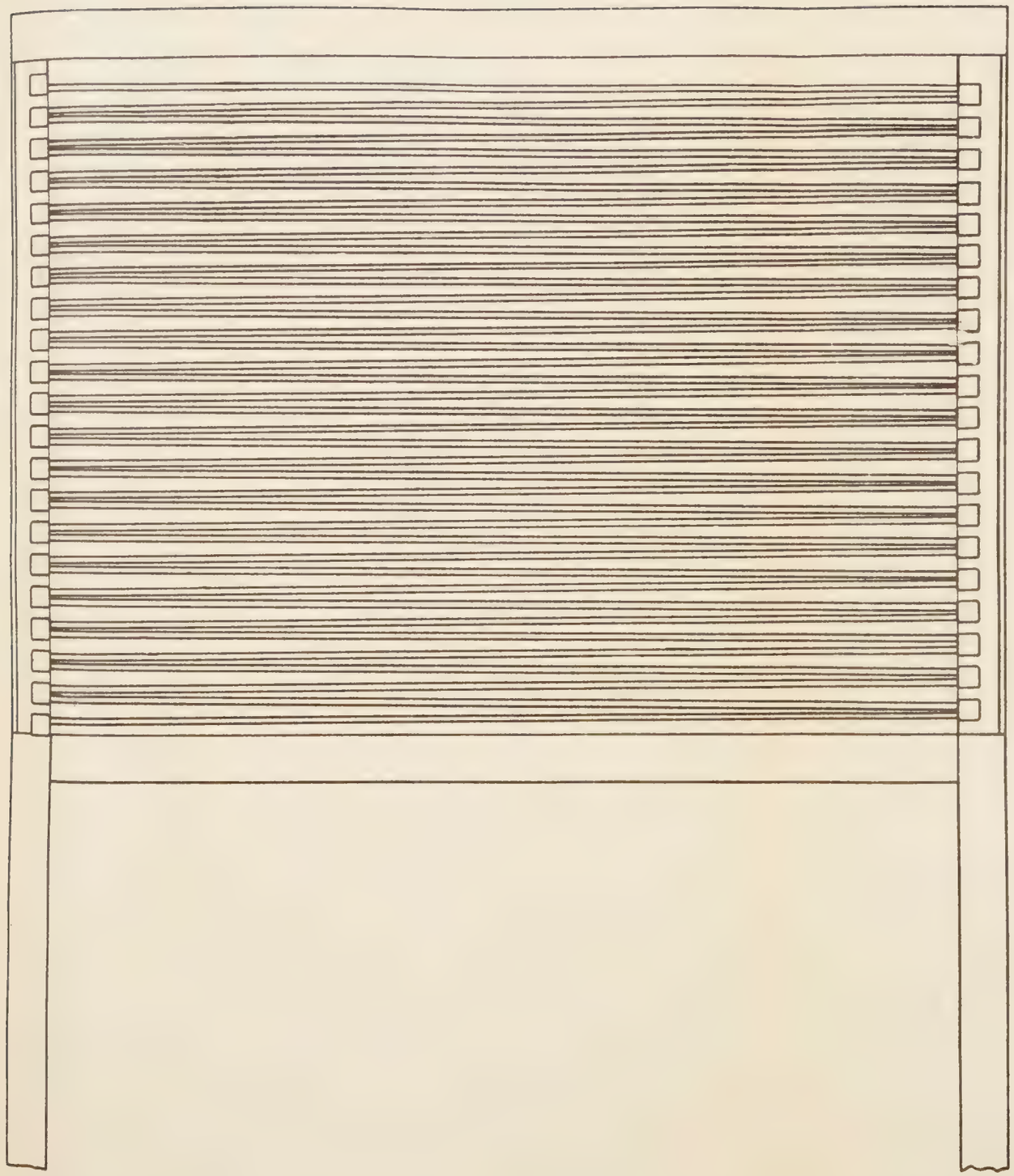
PLAINTIFF'S EXHIBIT Nº 6

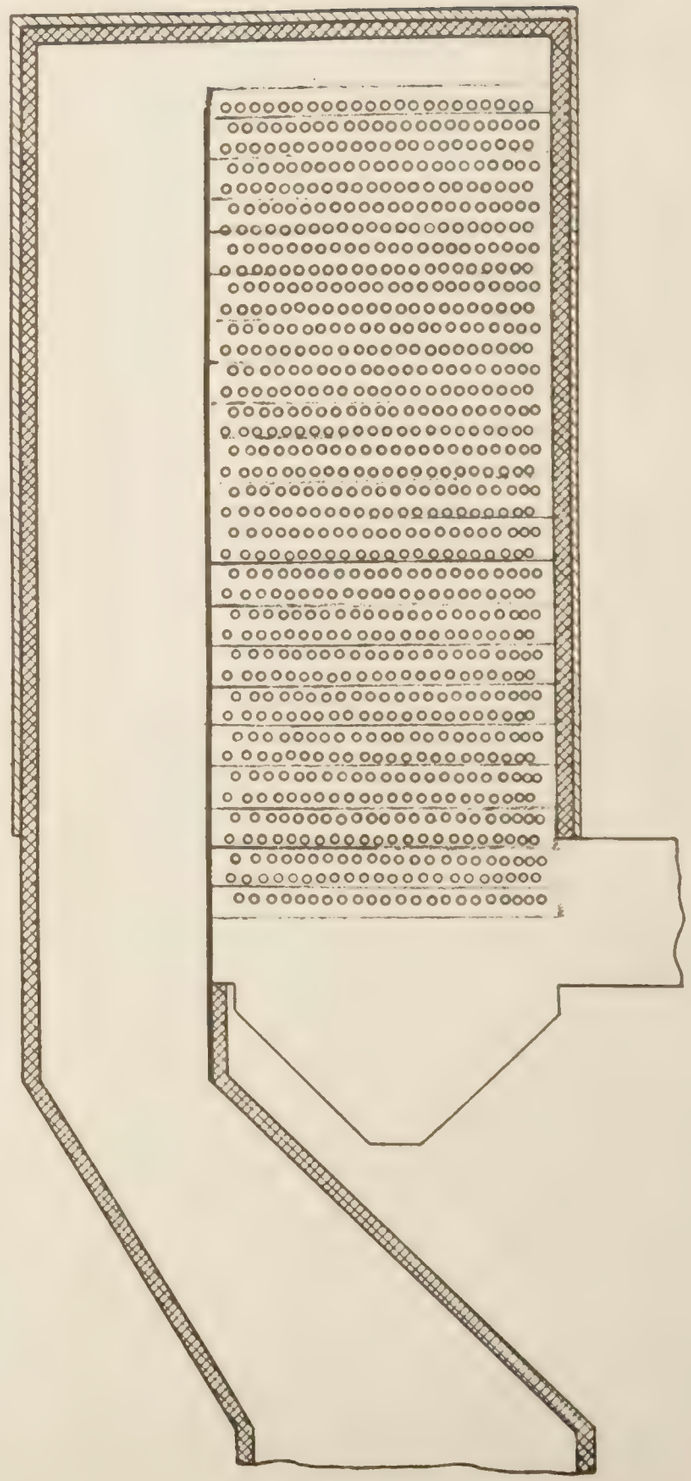
KEENAN DRAWING

EDISON ELECTRIC ILLUMINATING CO.

BOSTON, MASS

BABCOCK & WILCOX ECONOMIZER





PLAINTIFF'S EXHIBIT 7.

Work Order No. 4293 637

THE U. G. I. CONTRACTING COMPANY SPECIFICATIONS FOR ECONOMIZERS AT DEVON POWER PLANT

THE CONNECTICUT LIGHT & POWER CO., DEVON, CONN.

1. Number required 4 specification describes one.
2. Working system pressure 320 pounds per square inch
3. Two economizers to be used in conjunction with horizontal water tube boilers having a heating surface of 16,800 sq. ft. each. The other two economizers to be used in conjunction with horizontal water tube boilers having a heating surface of 15,300 sq. ft. each and equipped with side wall water screens having 400 sq. ft. 638 surface per boiler.

   Width of furnace in each case 21′ 6″.
4. Economizer design to be governed by conditions holding when Penna. Bituminous coal of 14000 B. T. U. heat value, as fired, having the following proximate analysis is burned.

   Fixed carbon..... 71.80%
   Volatile 16.40%
   Moisture 3.50%
   Ash 8.30%
   Sulphur ..... 1.14% (Separate analysis)
5. The boilers are to operate at a normal rating of 200% 639 and a maximum rating of 400% with performance data as follows:—

% rating	# of Steam	Approx. wt. of fuel burned	%CO2 Exit last pass	Feed Water temp.	Approx. flue gas temp.
100	50,000	5,200#	14	230°F.	500°F.
200	100,000	10,650#	13	230°F.	550°F.
250	125,000	13,300#	13	230°F.	580°F.
300	150,000	16,200#	12	230°F.	625°F.

640

350	175,000	19,650#	11	230°F.	662°F.
400	200,000	23,100#	10	230°F.	700°F.

6. General specifications for Economizers:

Description:— Economizers shall be designed and constructed in accordance with the 1924 code of the A. S. M. E. in so far as this code does not conflict with the laws and regulations prevailing at the place of installation.

Type — Horizontal steel tube

Arrangement — Above boiler, to take gas from uptake, located immediately back of steam drum. The gas to flow counter current to the feed water.

641

Size — Sufficient to give an increase in temperature of 60°F. under conditions holding when boiler is operating at 200% of rating.

Tubes — Seamless steel

Safety valves — Two 3½" consolidated form D. S. safety valves in accordance with A. S. M. E. code, set to blow at 360 pounds.

Blow-off valves — Each economizer shall be provided with Edwards blow-off valves and Everlasting guard valves, both valves shall be extra heavy flanged steel.

642

Outlets — Outlets shall be faced and drilled in accordance with A. S. M. E. 600# W. S. P. standard.

Supports — Supports for the economizer will be furnished and installed by the contractor.

Tools — The Contractor shall furnish one complete set of special tools and wrenches

necessary for the operation and maintenance of the equipment. 643

7. Cuts and Prints:—

Manufacturer to submit when bidding such dimensioned cuts or prints as to give a clear understanding of the design of the apparatus he proposes to furnish.

The manufacturer shall furnish the Purchaser or his Engineers within fifteen calendar days after the contract is placed, four sets of certified prints of outline drawings showing the scale the apparatus to be furnished. Also full information on any part of the equipment which may be needed by the purchaser, including such detailed shop drawings as are necessary. 644

The Purchaser or his Engineers will examine these certified drawings only for general design, general dimensions and apparent suitability, and will approve them or return them for changes desired. Such approval will not relieve the Contractor of responsibility to furnish equipment which will satisfactorily perform under the specified conditions. After drawings are approved, four copies shall be furnished as soon as possible. After installation is completed, two more copies of corrected drawings shall be furnished.

Two copies of any special operating instructions shall be furnished to the Engineers where economizers are shipped. 645

8. Erection:—

The Contractor will be responsible for the erection and preliminary operation of these economizers under the general direction of the Engineers.

9. Inspections and Tests:—

(a) A certificate of shop inspection by the Hartford Steam Boiler Inspection and Insurance Company shall be furnished by the Contractor before shipment.

646 (b) Purchaser's inspector shall have free access to manufacturer's plant during period of construction.

(c) After the economizers have been erected, they shall be given a hydrostatic test at 1–½ times the specified steam pressure and any and all other tests as may be required by law or ordinance.

All apparatus for these tests shall be furnished by the Contractor.

(d) If the Purchaser so desires, an acceptance test shall be run on one of the economizers at the expense of the Purchaser, and under the rules of the A. S. M. E. Test Code of 1923. This test shall be made within 180 days
647 after the economizers are placed in service.

10. Time of Shipment:—

State time to make shipment.

State time to complete shipment.

–3–

Work Order No. 4293

INSTRUCTIONS TO BIDDERS FOR ECONOMIZERS POWER HOUSE AT DEVON, CONNECTICUT THE CONNECTICUT LIGHT & POWER COMPANY

GENERAL

648 1. Duplicate proposals will be received at the office of the Purchasing Agent of the U. G. I. Contracting Company at Philadelphia, Pa., up to 4.30 P. M. December 15, 1925, for the work outlined in the enclosed specification.

2. Bid price shall be submitted on a sheet from all other data.

3. Bidders can visit the site and familiarize themselves with every phase of the work before submitting proposals.

4. All drawings and specifications furnished with requests

for bids remain the property of the Purchaser and shall be returned with the proposals. 649

5. The right is reserved to reject any or all bids.
6. The successful bidder shall enter into a written contract with the Purchaser for the performance of the work included in the specifications.
7. This contract will be drawn up by the Purchaser and will include Purchaser's and Contractor's Specifications and Instructions to bidders. In case of conflict between Purchaser's and Contractor's specifications, the Purchaser's specifications shall rule.
8. FORM OF PROPOSAL: 650

   Bidders are requested to state a lump sum price for furnishing, delivering and erecting the equipment specified.
9. Each proposal shall be accompanied by dimensioned drawings showing the equipment offered.
10. DELIVERY:

    Delivery and completion of erection desired May 1, 1926.
11. FACILITIES:

    (a) The plant is located on the N. Y., N. H. & H. Railroad and there is a siding entering the plant.

    (b) Water will be furnished free by the Purchaser. 651

    (c) Power will be furnished free by the Purchaser.

    (d) Power available is 220 volts A. C., 60 cycles, 3 phase, and 110 volts, 60 cycles, single phase.

    (e) Compressed air at 100 lbs. will be furnished free by the Purchaser.

    (f) Storage space will be available inside the property.

    (g) Office space with local telephone service, light and heat, will be furnished free by the Purchaser.

652 All long distance or pay calls will be charged to the user.

12. SHIPPING: Purchaser will furnish shipping instructions.

13. LABOR CONDITION: Open shop.

14. INFORMATION: The following information shall be given with each proposal and will be made a part of the contract entered into with the successful bidder.

(a) Heating Surface (——) sq. ft.

(b) Weight of economizers.

(c) Weight and size of largest piece.

653 –2–

(d) Shipping point.

(e) Date of shipment and time necessary to complete erection.

(f) Diameter, thickness, material and number of tubes.

(g) Draft loss through economizer at various ratings shown on specification.

(h) Pressure drop through economizer at various ratings.

(i) Feed water temperature outlet of economizer at various ratings.

654 (j) Description of tools and accessories included.

(k) Economizer supports.

(l) Provision for inspection and cleaning of economizer.

(m) Any other details wanted by Purchaser.

Plaintiff's Exhibit 7.

B. F. STURTEVANT COMPANY 655

(Letter Head)

January 18, 1926.

The U. G. I. Contracting Co., Broad & Arch Sts., Philadelphia, Pa.

Attention: Mr. J. H. Hubbs.

We proposed to furnish you the apparatus described in the attached specifications to be delivered
and erected at The Connecticut Light & Power Co., Devon, Conn.

The price of this apparatus is as noted in the following specifications and you are to pay the same to us as follows:

TERMS: 50% on delivery of material at the site of the 656
work; 25% thirty days thereafter, and 25% thirty days after completion of erection, it being understood that in the event erection is delayed by you, final payment shall be made one hundred twenty (120) days after delivery of the material. Pro rata payments will be made on partial delivery and erection.

In case of delay, not of our making, the price shall be paid to us at such time as it would have been payable had such delay not occurred.

The price of these four (4) Economizers is SIXTY-SEVEN THOUSAND THREE HUNDRED AND TWENTY DOLLARS ($67,- 657
520.00).

–2–

We take pleasure in quoting you on four (4) Economizers described in your specifications, for Boilers #5, 6, 7, and 8 at the Devon, Conn. plant of the Connecticut Light & Power Co.

WORKING CONDITIONS

We understand that two (2) economizers are to be used with boilers having a heating surface of 16,800 sq. ft. each.

658 The other two economizers to be used in boilers having a heating surface of 15,300 sq. ft. each, equipped with side water walls having 400 sq. ft. of surface per boiler.

We understand that the working steam pressure is 320# per sq. inch.

The selection of the economizer was based on Pennsylvania bituminous coal of 14,000 B. T. U. heat value as fired, and having the following approximate analysis:—

Fixed Carbon	71.8%	
Volatile	16.4%	
Moisture	3.5%	
Ash	8.3%	
Sulphur	1.14%	(separate analysis)

659

Our guarantees are based on the following working conditions, which form a part of your specifications:—

% rating	# of Steam	Approx. wt. of fuel burned	%CO2 Exit last pass	Feed Water temp.	Approx. flue gas temp.
100	50,000	5,200#	14	230°F.	500°F.
200	100,000	10,650#	13	230°F.	550°F.
250	125,000	13,300#	13	230°F.	580°F.
300	150,000	16,200#	12	230°F.	625°F.
350	175,000	19,650#	11	230°F.	662°F.
400	200,000	23,100#	10	230°F.	700°F.

660

APPARATUS

Four (4) Units, each consisting of our type *Y* Economizer containing 20 sections, each section consisting of 9–16 ft. pipes. The pipes are rolled into square steel headers. On these pipes are steel discs spaced equally, and put on the tube in such a manner that an absolutely tight contact is assured. So tightly, in fact, are these discs put on our pipes that it really sinks into the steel pipe and forms a part of it. This is the secret of the very high heat transfer which we

obtain from this machine. After the discs are put on the 661
pipes, the pipes are then lead coated both inside and out, to resist the corrosive action of sulphuric acid gases on the outside, and the oxygen on the inside.

–3–

The sections are completely assembled at our plant and tested to 750 lbs. pressure with water at 210°. This insures tight sections before they leave the plant, and also facilitates the quickness of erection.

Our proposal also includes a steel structure consisting of vertical columns with angle iron tracks spaced equally on these columns, on which the sections rest. The assembled 662
sections are slid into position on these tracks, just as you would slide a drawer in your desk. Connecting bends are then put on between adjoining sections, so that the water flows from the bottom of the machine to the top thru each section, or from the top to the bottom as you prefer.

We have not considered it necessary to select a machine that would handle all of your gases at the peak load, as in this case the machine would not be economical at your normal rating of 200%. Our machine will enable you to handle from 300% to 350% thru it, and a by-pass is to be provided to take care of the extra amount of gas to the higher rating. Insulated doors and panels are provided for the front and 665
rear end of each machine.

Our proposal includes steel plate on the pipe sides of the economizer, but no other flue work. It also includes the structural steel supports, as shown on our drawing, and the sections with their connecting bends.

No soot blowers are included in this proposal.

We will furnish for each economizer two (2) 600# standard 3–½" Consolidated Form DS safety valves, set to blow at 360# pressure.

Plaintiff's Exhibit 7.

664 We will also for each economizer furnish one (1) Edwards 600 lb. standard blow off valve, and one (1) Everlasting 600 lb. standard guard valve. Both valves will be extra heavy flange steel.

With this proposal we include our Catalog #334 and our Blue Print #C15–7250–A which gives a general idea of proposed arrangement.

INSPECTION AND CLEANING

Repairs to this type of economizer are exceedingly simple. For four machines we would recommend keeping on hand two (2) spare sections, completely assembled in case of
665 trouble with a tube. It is only necessary to disconnect two of the 180° bends and draw the section out on its track, placing it at some convenient location for repairs. The spare section could then be inserted in its place and the two bends connected up again. Work can then easily be done on the section that has been giving trouble, and, if necessary to put in a new pipe, the defective pipe can be cut off, just as you would cut off a boiler tube. A new pipe is inserted in the hole of the rear header and pushed back as far as it will go. This allows it to clear the front header, and it is then inserted into the hole in the front header and easily rolled in.
666 Closure caps are provided for closing the holes in the headers opposite the pipes. The holes are required for rolling the tubes, inspection and cleaning. The caps are described in page 6 of the attached bulletin #334.

–4–

GUARANTEED PERFORMANCE

Per cent rating	100	200	250	300	350	400
Pounds of water per hr.	50000	100000	125000	150000	175000	200000
Pounds of gas per hr.	80000	164000	204000	250000	300000	300000

Plaintiff's Exhibit 7.

667

Initial temperature gas °F	500	550	580	625	662	700
Initial temperature water °F	230	230	230	230	230	230
Final temperature water °F	315	313	315	322	328	324
Temperature rise °F	85	83	85	92	98	94
Final temperature gas °F	264	326	350	380	407	419
Draft loss, inches water	0.26	0.95	1.53	2.40	3.58	3.60
Lbs. Water pressure drop	2.5	4.5	6	9	12	15

GENERAL DATA

668

Heating surface, sq. ft.	— 9,000
Total weight, lbs.	—73,000
Weight largest piece, lbs.	— 2,130
Number of tubes,	— 180
Number of sections	— 20

Pipes	2–¼″ O. D. 1–⅞″ I. D. cold drawn, annealed, seamless steel.
Headers	6–½″ square x ¾″ thick cast steel
Caps	Steel plug, copper gaskets, steel washer and nut.
End doors	2″ insulation.
Side sheets	Steel sheets no insulation included
Tools	A full set including wrenches and expander.

669

–5–

STATE REGULATIONS

"We represent that any design and / or material furnished and / work done under this agreement shall conform with all laws, rules, and regulations of the State, or part or branch thereof, wherein the material is to be used or work is to be done, and agree to correct at our own cost and expense any such design and/or material furnished and/or work done which does not comply with such laws, rules and regulations.

Plaintiff's Exhibit 7.

670 LIABILITY PERSONS AND PROPERTY

"The work covered by this agreement shall remain in our possession and control and be at our sole risk until completion and delivery thereof, in accordance with the terms of this contract, and we agree to protect, indemnify and save you harmless from any and all loss and/or liabilities arising from injuries to mechanics, laborers, or any other persons whomsoever employed in the construction of said work or otherwise employed on or coming upon or near said premises, and from and against any damage to property adjacent thereto, and from and against any and all loss and
671 for liabilities for damage or injury to any persons or property whatsoever in any manner resulting from or caused by the performance of this agreement, or any work relating thereto, or any portion of said work.

PATENTS

"In the event of any suit, claim, or proceedings being brought against you and/or the Owner for the infringement of any letters patent of the United States of America by reason of the use of any device, design, or apparatus furnished by us under the terms of this agreement, we agree to forever protect, indemnify, and save you and/or the Owner
672 harmless, from and against all costs, damage, loss, or expense which you and/or the Owner may incur or undergo by reason thereof, provided that you or the Owner give us immediate notice in writing of the institution of such suit, claim, or proceedings and permit us to defend the same through our counsel.

"In case such device, design, or apparatus is in such suit held to constitute infringement, and its use is enjoined, we, if unable within a reasonable time to secure for you and/or the Owners the right to continue using said device, design,

or apparatus, by suspension of the injunction, or by securing for you and/or the Owner a license, or otherwise, will at our own expense, either replace such device, design or apparatus with non-infringing device, design, or apparatus, or modify it, without decreasing the efficiency, so it becomes non-infringing, or remove the said enjoined device, design, or apparatus, and refund the sum paid therefor. 673

GUARANTEE

"We agree to correct and shall have the right to correct, either by repair or replacement, at our own cost and expense, any defects in either workmanship or material that may develop under normal and proper use, within one year from the date of completion of the work covered by this agreement, and such corrections shall complete our obligations hereunder". 674

We expect you will give us at all reasonable times access

–6–

to said apparatus furnished by us, and that said apparatus will not be altered except by us or with our knowledge and consent.

DELIVERY

Delivery of the machines and erection can be completed by May 1st, 1926.

We can start shipping within two (2) months after receipt of complete information in our Works. It takes approximately three (3) weeks to erect each machine. 675

We charge TEN DOLLARS ($10.00) per day plus expenses for our erector's service in case they are needed after completion of erection.

GENERAL

The guarantee specifically set forth above is our only guarantee and is made in lieu of all other warranties expressed or implied by law or trade usage, and of all other

676 obligations or liabilities on our part, and we neither assume nor authorize any other person to assume for us any other liability in connection with the sale of our apparatus.

Where tests are to be run, you are to give us ample notice and at our election permit our representative to be present, and supply us with duplicate reports of all data covering such tests, and we reserve the right to make any changes necessary.

We shall not be held responsible in any way for the furnishing of foundations, masonry work, grouting, supports, builder's and joiner's work, wiring and piping, obtaining suitable access to the premises, excavation and making good
677 again, drayage, or any expense incidental to any of this work.

When we erect the apparatus or furnish labor to assist in its erection, we are to be unrestricted in our choice of employees for this work; and if on your request we employ labor selected by you (individually or otherwise) then you shall assume and repay to us any increase in wages over the current wages of our employees, resulting from such employment.

If we are required to pay any tax or charge hereafter imposed by governmental authority, upon merchandise herein
678 described, or the production, sale, transportation, or delivery thereof, or upon any feature of this transaction, you will, upon demand, assume such obligation or reimburse us for any outlay incurred.

This proposal is in no way binding upon us until countersigned at our home office. When accepted and countersigned, this proposal and attached specifications will contain and constitute the entire agreement with us, superseding all previous understandings regarding this apparatus, and will be an indivisible contract of sale. All representations rela-

tive to this apparatus relied upon by you in accepting this 679
proposal are specifically set forth herein and your signature

–7–

is acknowledgment of your receipt of duplicate of this contract.

The acceptance of your order constitutes a complete and binding contract which cannot be modified or cancelled without written consent of both parties.

No cancellation of this order will be entertained.

The said parties for themselves, their successors, executors, administrators and assigns do hereby agree to the full performance of the covenants herein contained. 680

Accepted this April 10, 1926 day of 19

B. F. STURTEVANT COMPANY,
By H. W. Daley Sales Mng'r. (Title)

THE U. G. I. CONTRACTING COMPANY
By J. H. Hubbs,
Asst. Purchasing Agent (Title)

Countersigned this 4th day of May, 1926.

B. F. STURTEVANT COMPANY,
By E. B. Freeman, Vice Pres. (Title)

681

[MEMO. Attached to this exhibit is the catalogue which comprises Plaintiff's Exhibit 4 reproduced at pages 197 to 208, inclusive.]

PLAINTIFF'S EXHIBIT 8.

220

Sturtevant

FUEL ECONOMIZERS & AIR HEATERS

BSE

CATALOG No. 150

230

Sturtevant

FUEL ECONOMIZERS AND AIR HEATERS

STURTEVANT ENGINEERING SERIES

CATALOGUE NUMBER 150

SECOND EDITION
JULY 1911

B. F. STURTEVANT CO.

GENERAL OFFICE AND WORKS

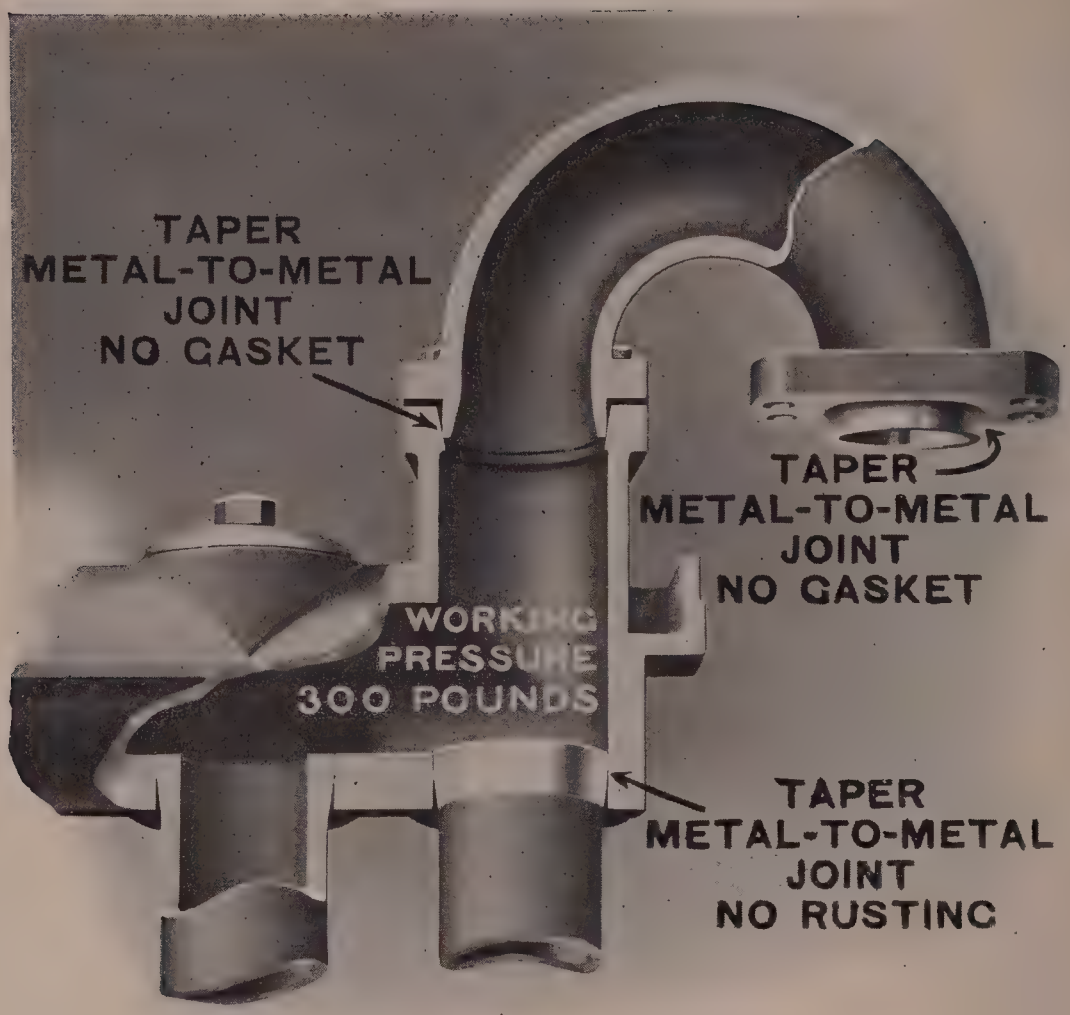
HYDE PARK, MASS.

Boston, Buffalo, Chicago, Cincinnati, Seattle, Cleveland, Hartford, Minneapolis, New Orleans, New York, Philadelphia, Pittsburg, Rochester, San Francisco, St. Louis, Toronto, Washington, Montreal

STURTEVANT ENGINEERING COMPANY

London, Glasgow, Paris, Berlin, Stockholm

232


TAPER
METAL-TO-METAL
JOINT
NO GASKET
TAPER
METAL-TO-METAL
JOINT
NO GASKET
WORKING
PRESSURE
300 POUNDS
TAPER
METAL-TO-METAL
JOINT
NO RUSTING

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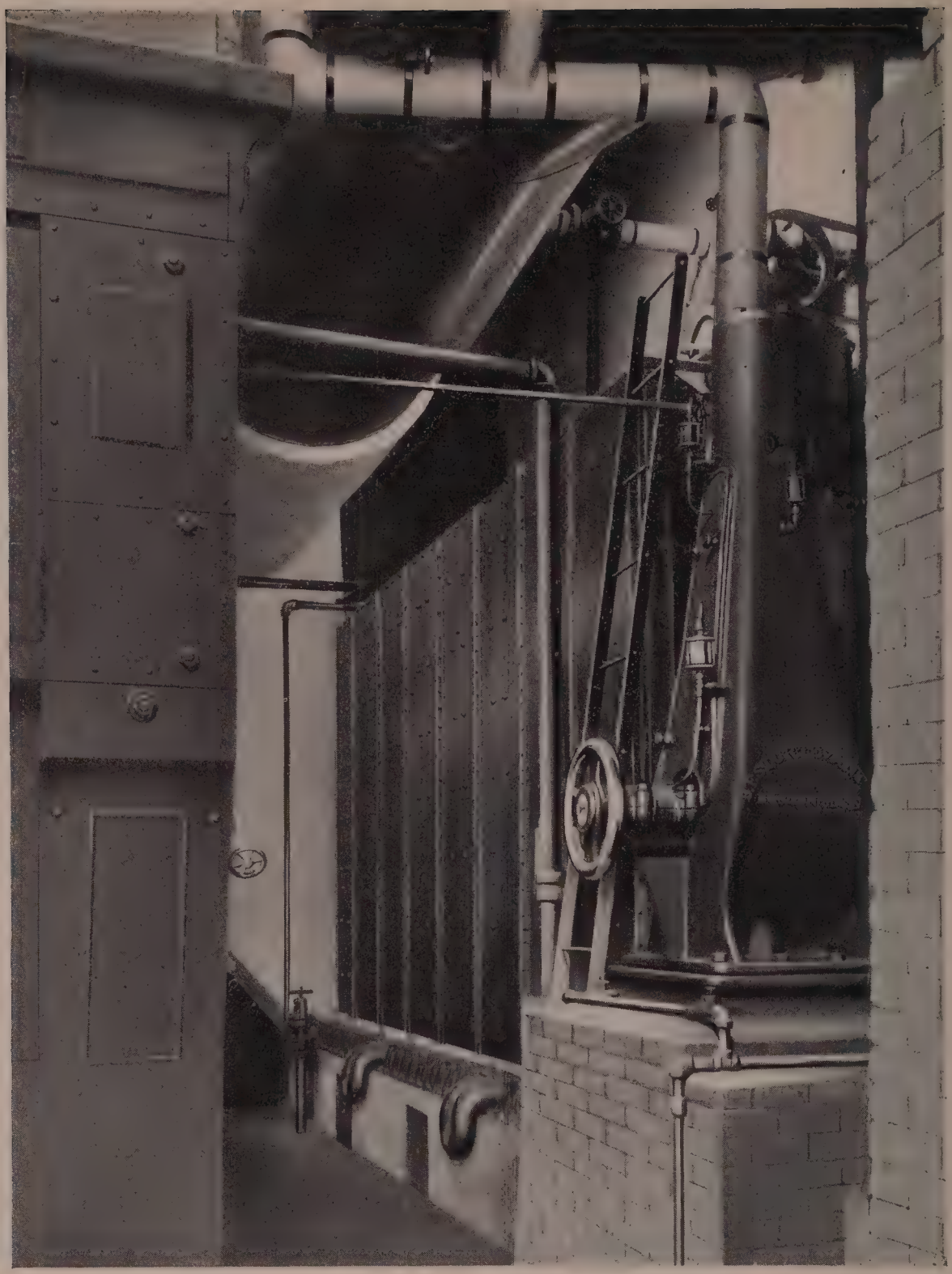


ECONOMIZER AT THE NORFOLK AND NEW BRUNSWICK HOSIERY CO.

STURTEVANT FUEL ECONOMIZERS

The principle of the Sturtevant Economizer is to conduct the hot waste gases which have passed through the boilers and are escaping into the chimney around and between a system of cast-iron pipes containing feed water, thus heating a large volume of feed water to a high temperature before it enters the boilers, accomplishing all this saving in fuel and gaining this extra boiler capacity by the use of otherwise wasted gases.

WHAT THE STURTEVANT ECONOMIZER DOES

SAVES FUEL

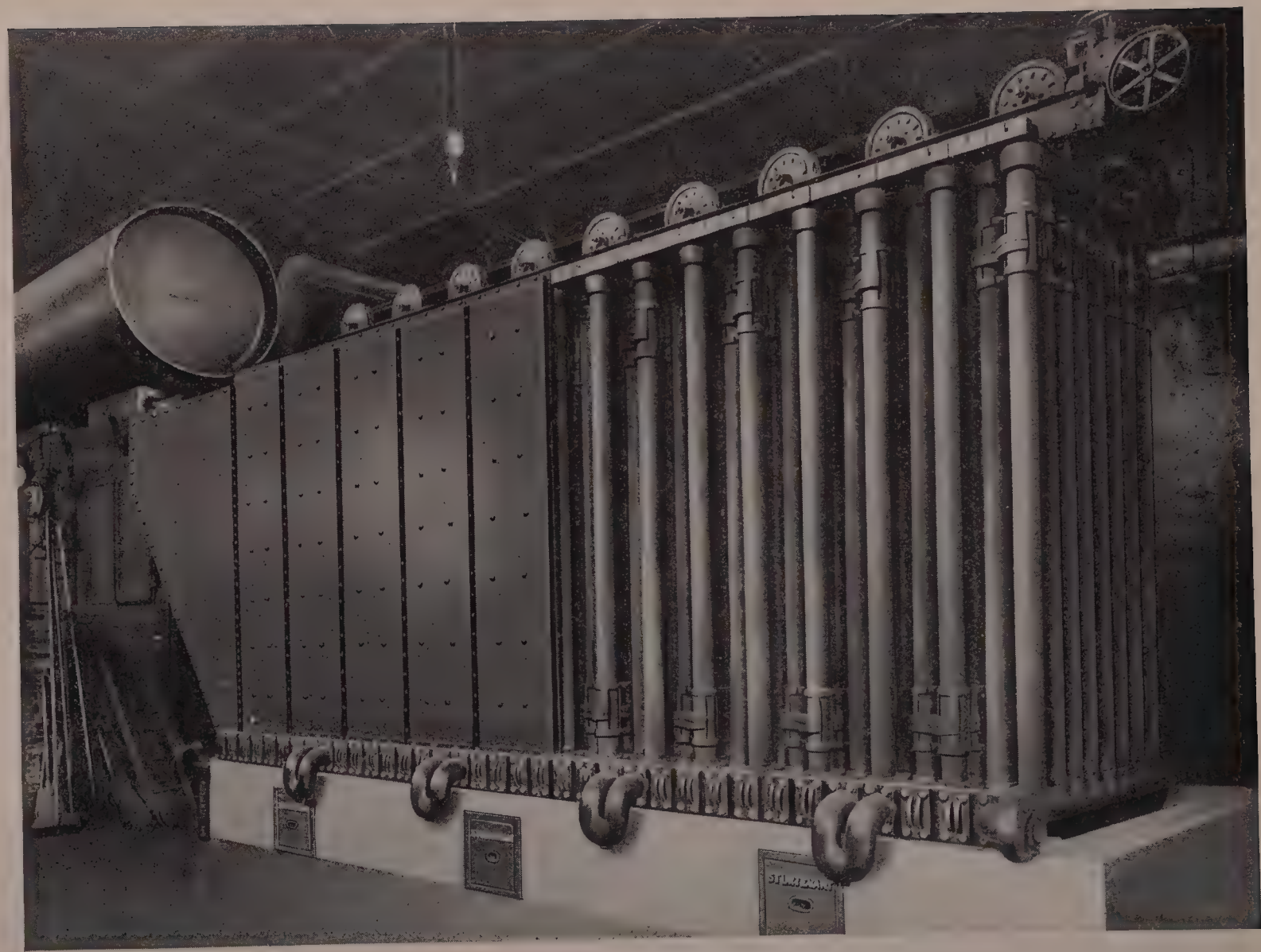
It saves 10 to 20 per cent in fuel by supplying the boiler with water almost to the boiling point, thus saving the coal necessary to heat cold feed water.

INCREASES BOILER CAPACITY

It increases the boiler capacity 20 to 40 per cent, as the large reserve of hot feed water, always ready in the economizer, leaves the boilers only the work of bringing the hot water to the vaporizing point. This enables the boiler to convert much more water into steam when aided by an economizer.

REDUCES REPAIRS

By heating the feed water the boiler gets none of the sudden expansion and contraction due to the change of temperature when cold water is fed, thus avoiding many leaks and prolonging the life of the boiler. The purifying of the water by lessening the scale increases the durability of the boilers as a whole by reducing the tendency to bag.



ECONOMIZER AT THE CLEVELAND CLIFFS IRON CO.

STURTEVANT FUEL ECONOMIZERS

PURIFIES FEED WATER

The feed water is purified by heating in the economizer, and in circulating through the economizer pipes a large part of the impurities settle into a section which is easily cleaned out. This gives purer water to the boilers, reducing the amount of scale and allowing the boilers to steam much more freely.

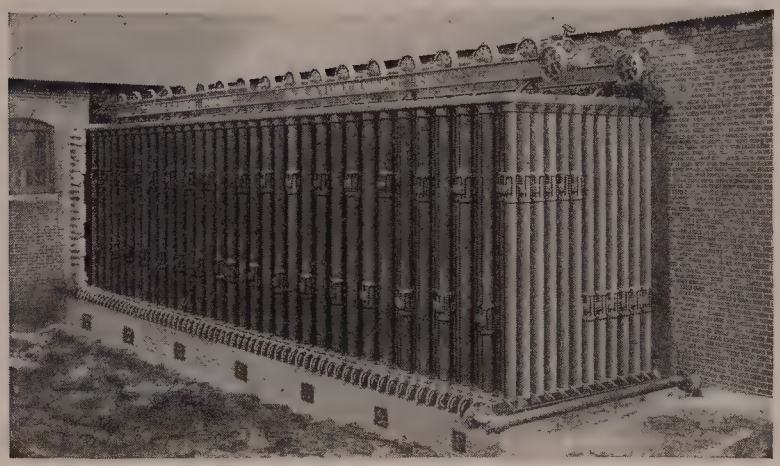
REDUCES SOOT AND SMOKE

It reduces the amount of soot in the chimney and lessens smoke from the stack, as the hot gases in passing through the economizer deposit a large amount of soot on the economizer pipes. This soot is automatically scraped from these pipes and deposited in a soot chamber under the economizer.

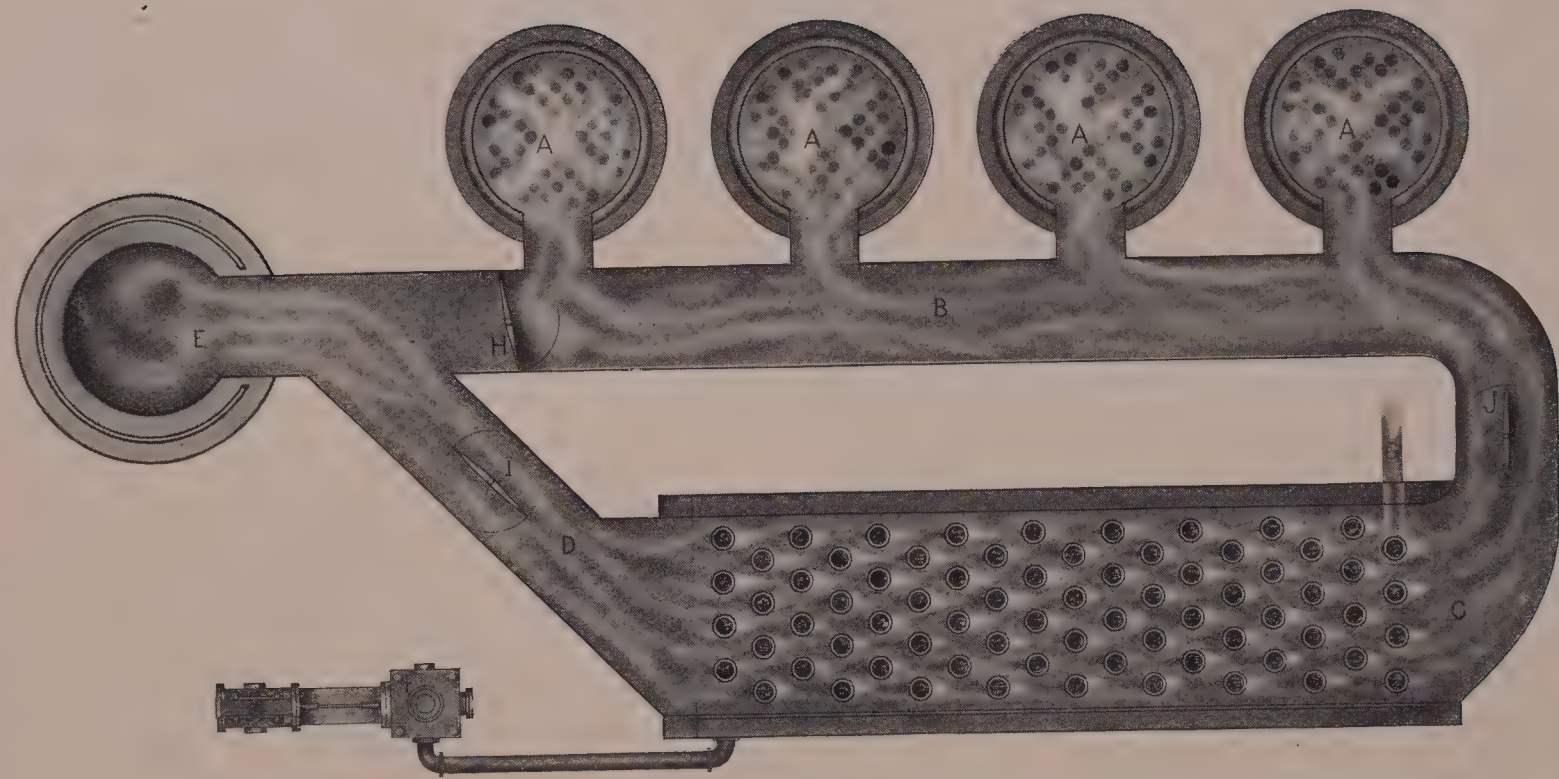
USED AS A HOT WATER HEATER

Textile mills, paper mills, and many other plants needing large quantities of hot water in processes of manufacture draw this from the supply in the economizer, thus getting their hot water at no fuel cost.

All these savings are secured
from otherwise wasted gases.



ECONOMIZER AT INTERNATIONAL PAPER CO., RUMFORD FALLS, ME. BEFORE ENCLOSING



The hot gases leave the boilers A, pass through flue B, and enter the economizer casing at C. The gases then pass by and around the economizer pipes filled with feed water, heating the water to a high temperature. After reducing their heat in raising the temperature of the feed water the gases pass through flue D to chimney E. The feed water from pump F passes through the economizer pipes and enters boilers through pipe G, having been greatly raised in temperature by the impinging hot gases. H is the by-pass damper which compels gases to go through economizer. I and J are dampers by shutting which and opening H the gases can be passed directly to the chimney.

SAVING EFFECTED WITH ECONOMIZERS

The table below gives results of fourteen miscellaneous Sturtevant Economizer installations showing the amount that the temperature of the gases are reduced while passing through the economizer and the amount that the temperature of the feed water is raised by transferring to it the heat taken from the otherwise wasted gases, and the resulting percentage of fuel saving. The figures on this table taken in connection with the explanation on page 11 will show in a general way the large investment returns that an economizer brings to the average plant.

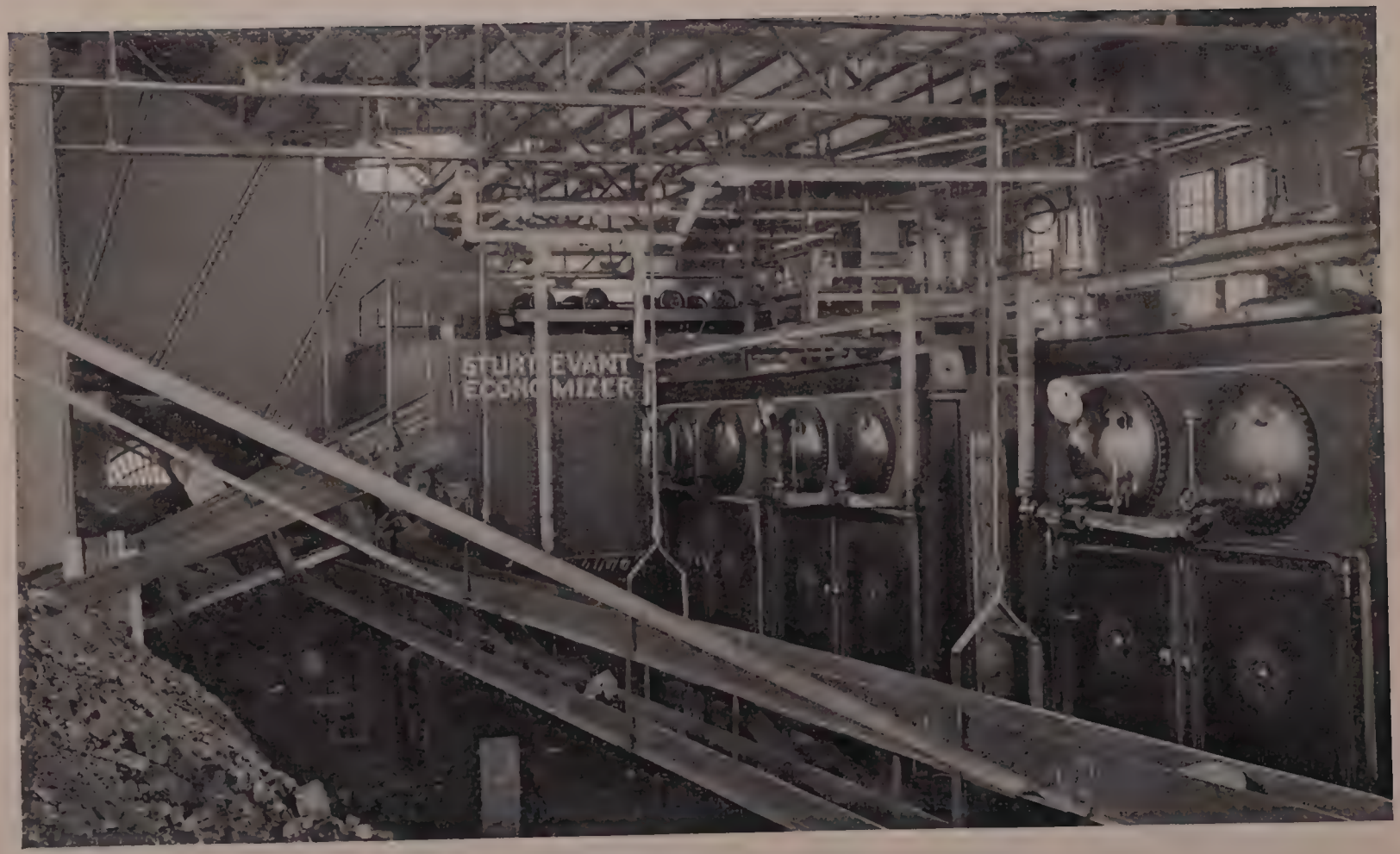
EXPLANATION OF TABLE

The theoretical fuel saving when feed water enters at 120° F. and with 150 pounds boiler pressure is 1 per cent in fuel to every 11 per cent temperature rise in the feed water. The percentages of saving as shown in the table below vary from this 11% basis, some being more and some being less, as they are taken from plants with various boiler pressures and different entering temperatures of the feed water.

Item	Gases Entering	Gases Leaving	Water Entering	Water Leaving	Gain in Water	Per Cent Saving	Kind of Draft
1	510	290	130	260	130	12.0	Chimney
2	475	215	71	230	159	13.9	"
3	415	200	100	240	140	12.5	Mechanical
4	525	375	78	198	120	10.5	"
5	500	290	135	240	105	9.8	"
6	575	290	160	320	160	15.3	"
7	667	308	169	269	100	9.6	"
8	480	250	110	260	150	13.7	Chimney
9	600	375	90	230	140	12.5	Mechanical
10	600	350	110	240	130	11.8	Chimney
11	410	204	120	285	165	15.2	Mechanical
12	480	240	90	210	120	10.7	"
13	505	212	84	276	192	17.1	"
14	595	299	130	311	181	16.8	"

The sum of the percentages of fuel saving of the 14 installations divided by 14 gives the average fuel saving of 13%, which is fair and conservative.

14)181.4
13%



ECONOMIZER AT THE J. R. BOOTH COMPANY

RETURN ON INVESTMENT EFFECTED BY AVERAGE ECONOMIZER INSTALLATION

INVESTMENT RETURN

The actual saving which an economizer makes over the interest on the investment plus a fair percentage for depreciation and repairs is a strong factor in determining the advisability of installing an economizer, although in addition to the fuel saving as shown below, there are the advantages of greater boiler capacity and less boiler repairs. Carrying in mind the average fuel saving by actual tests as shown on page 9 as 13 per cent, the following figures will give a fair conservative estimate of the actual investment return of an economizer in the average plant.

Assuming a 1000 H.P. boiler plant operating 10 hours a day at full load with 10 per cent night load, the average coal consumption at 4 pounds per boiler H.P. per hour, the cost of good bituminous coal at $4.00 per ton, the cost of economizer completely installed at $5000.

1000 boiler H.P. × 4 lbs. coal per B.H.P. per hour × 10 hrs. per day = 40,000 lbs. of coal + 10 per cent night load = 44,000 lbs. of coal used each 24 hours.

44,000 lbs. ÷ 2240 = 19.64 tons per day × $4.00 = $78.56 fuel cost per day. Average fuel saving by economizer as shown on page 9 being 13 per cent, the return on investment would be as follows:—

13% of $78.56 daily fuel cost × 300 days per year	$3063.84
Interest on investment, depreciation, repairs, etc., at 10%	500.00
Balance	$2563.84

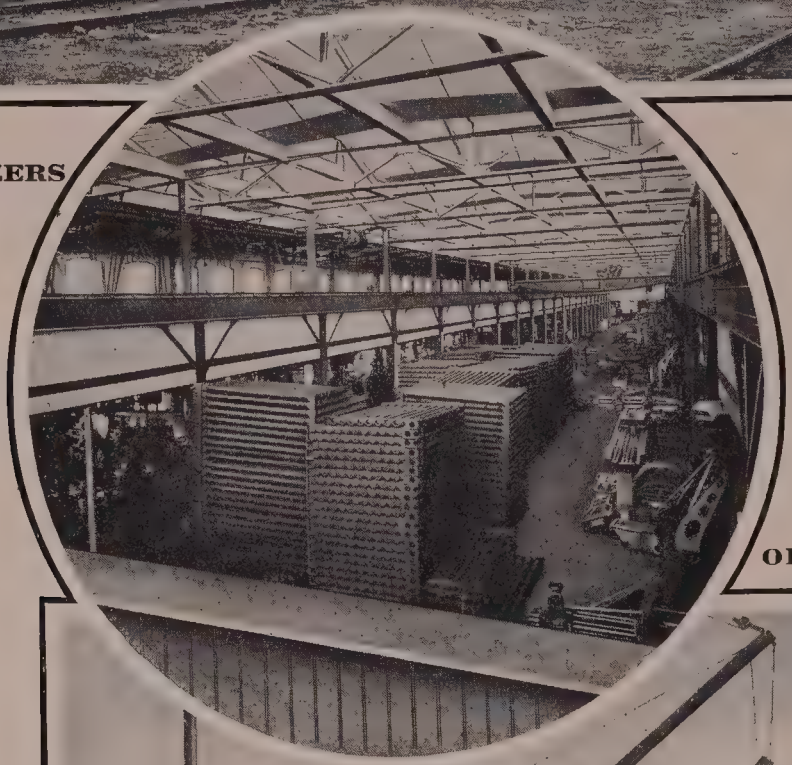
$2563.84 ÷ 5000 = 51.3% annual return on investment.

DIFFERENT OPERATING CONDITIONS

The type of plant and hours of operation per day have a direct bearing on results, as a plant running twenty-four hours per day as in the case of most paper mills, will give practically double the investment returns of a plant running ten or twelve hours per day. Thus while the savings of a plant running ten hours a day would take two years to pay for the cost of the economizer, a plant running twenty-four hours a day should pay for the economizer in one year.

Note.—The savings due to the smaller amount of coal handled, lighter load on boilers and purified feed water are in addition to fuel saving as shown above.

SHIPPING ECONOMIZERS



A SECTION OF OUR PLANT

LOADING ECONOMIZERS

STURTEVANT GUARANTEES

Although we subject all our Economizers before they leave our plant to a test by hydraulic pressure much higher than they will ever be subjected to after installation, and furthermore test them again after installation to considerably more than their working pressure, still some purchasers not knowing that our method of testing economizers and our **metal-to-metal** joints practically eliminates the chance of any serious repairs, desire some guarantee on this point. For purchasers desiring this, we have adopted the two following guarantee forms which we have found from past experience that buyers consider very fair and liberal.

ONE-YEAR GUARANTEE

On all our economizers we positively guarantee to ship at no charge f.o.b., Readville, any and all parts that prove in any way defective within a period of one year from installation.

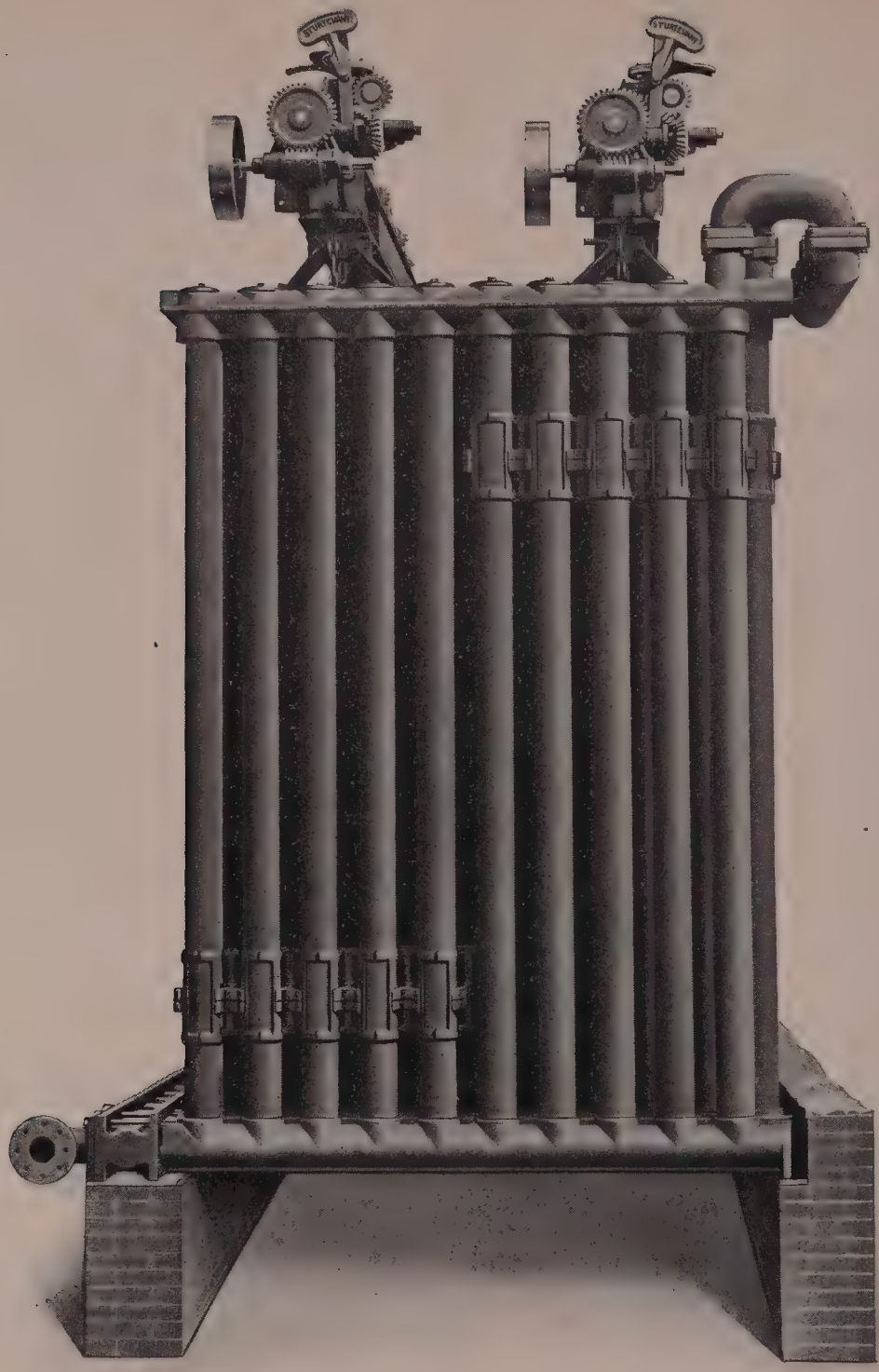
As all parts of our economizer are made to absolute standards, and as we use no rust joints, making the substituting of parts a simple matter, this form of guarantee covers very thoroughly any chances of repairs that may come up for a year from installation.

TEN-YEAR GUARANTEE

For one per cent per year of the contract price of our economizer we will guarantee for ten years to furnish any necessary parts and ourselves make any repairs not due to negligence or wrong use of the apparatus.

This form of guarantee gives a buyer who has never before purchased a Sturtevant Economizer a definite security for a considerable term of years.

Note.—Many of our economizer sales now are to various plants under one ownership where they have already tried out the Sturtevant Economizer and have proved its saving to them and know its strong construction, and so the matter of guarantee is not of much moment to them and often never considered.



HIGH PRESSURE TYPE. 300 LBS. PRESSURE. ALL JOINTS METAL-TO-METAL

WHERE THEY ARE PROFITABLY USED

Economizers are being profitably used in cotton and woolen mills, electric light and railway power plants, steel and wire mills, smelting plants, cement kilns, sulphite fibre plants, brick kilns, and in steam plants of all kinds.

They are used as a hot water supply in laundries, hotels, and dye houses, bleacheries; in fact in all plants where quantities of hot water are needed for manufacturing purposes.

TYPES AND SIZES

We make economizers to suit the requirements of each plant, but they all follow the one general design, and are made in three types: the Standard, the High Pressure, and the Pony economizer.

THE STANDARD

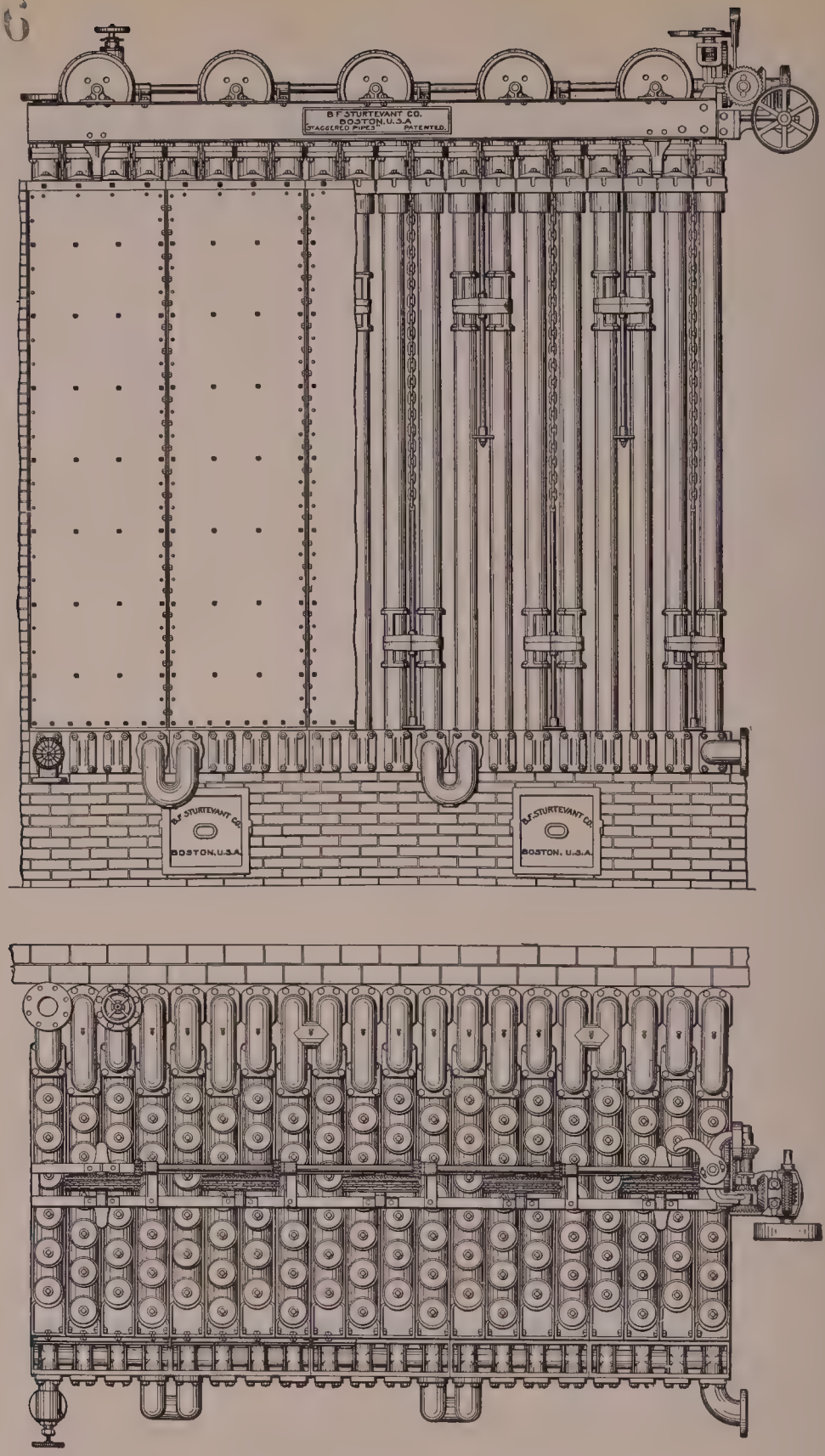
The Sturtevant Standard Economizer is best adapted for boilers with a capacity of 300 horse power and over, and is made for working pressures of less than 200 pounds per square inch.

HIGH PRESSURE

The High Pressure type is designed for working pressure of over 200 pounds per square inch. The **metal-to-metal** taper joints are the great point of superiority about the Sturtevant Economizer. When we force these ground taper **metal-to-metal** joints together by hydraulic pressure and test them under higher pressure than they will get in operation, we know that they must stay tight, as there is no gasket to blow or burn out, and there is absolutely no way they can leak.

THE PONY

The Pony Economizer is designed for use in plants with less than 350 horse power, and is made only for working pressures of less than 200 pounds. Small steam plants are more and more installing this size economizer, and find its saving pays for the economizer in from one to two years.



DRAWING OF THE STURTEVANT TYPE M ECONOMIZER

GENERAL DESCRIPTION

CONSTRUCTION

The Sturtevant Economizer is made up of cast-iron pipes arranged vertically in rows or sections which are connected by top and bottom cast-iron connecting chambers or headers. The whole apparatus is enclosed in a brick or a metal-asbestos casing, and is so placed in the power plant that all waste gases from the boilers are conducted among and between the economizer pipes in passing to the chimney.

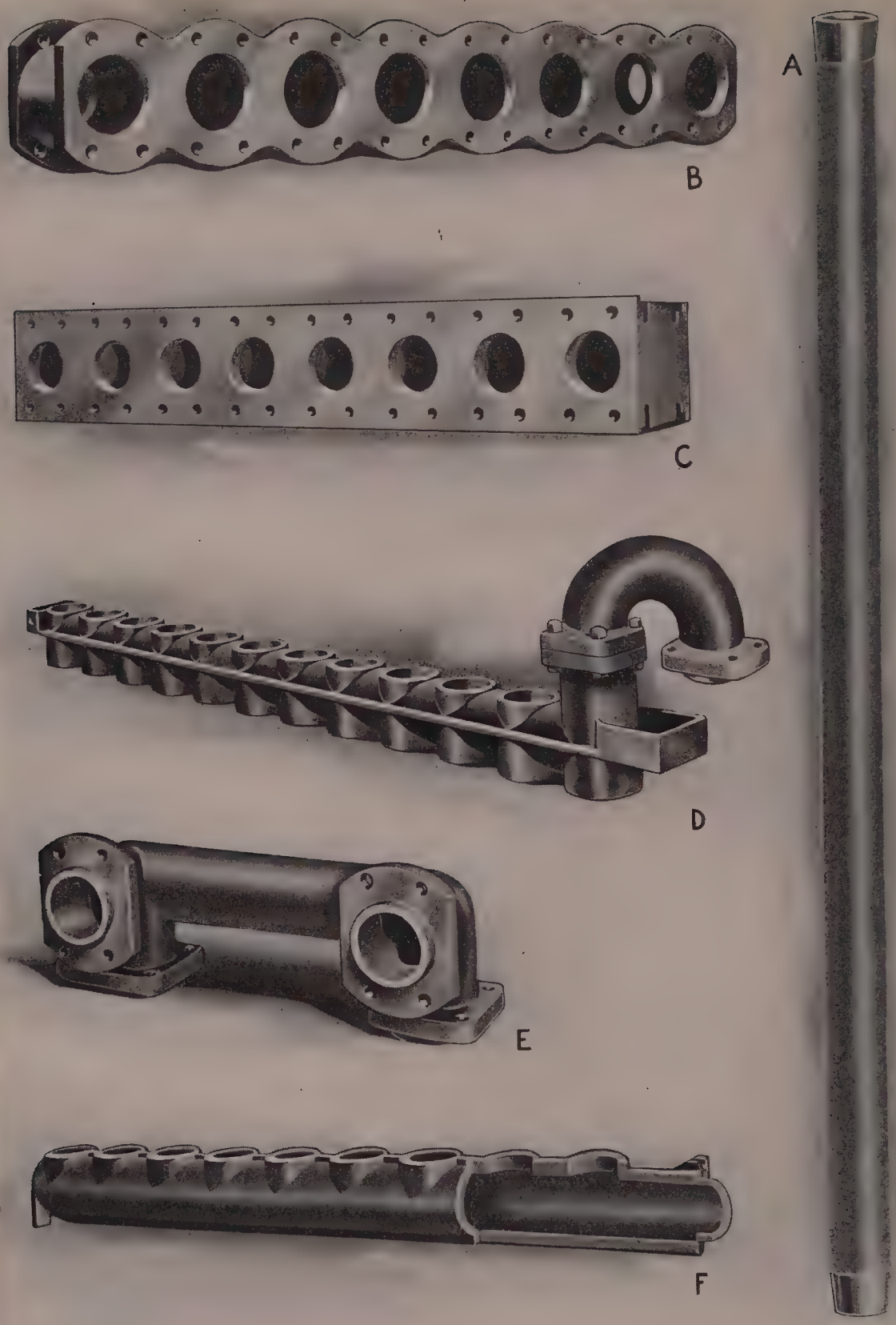
The feed pump supplies water to the economizer pipes, the water entering where the cool gases leave the economizer and leaving where the hottest gases enter (see p. 8), thereby heating the feed water to the highest temperature.

Common Form, Straight Rows

Sturtevant Staggered Pipes
Patented May 26, 1903

The pipes in the Sturtevant Economizer are placed staggered, an arrangement in which the pipes in one section being placed opposite the spaces of the adjacent section, the hot gases must completely envelop the cast iron water pipes and impart their heat to them much more quickly than when passing on the sides only of the parallel rows, as shown by accompanying illustration.

Note.—Although by using the staggered arrangement feed water can be heated to the same temperature with less piping than when the pipes are in straight rows, still since in some instances for special reasons the straight rows are preferred, we build economizers with this pipe arrangement.



PARTS OF HIGH PRESSURE ECONOMIZER

DETAIL CONSTRUCTION

The upright water pipes (Fig. A), $\frac{3}{8}$ inches in thickness, $4\frac{9}{16}$ inches in diameter, and either 9 or 10 feet long according to specifications, are cast of the best tough gray iron. They have accurately machined **metal-to-metal** taper fits at both ends, and are forced by hydraulic pressure into the top and bottom connecting chambers or headers (Figs. D and F), which are so machined as to make an absolutely tight **metal-to-metal** joint without any rusting. This feature of the taper no-rust joint is of great value in case of the necessity of removing a pipe, as shown on pages 22 and 23.

PIPES

In the Sturtevant Economizer the tapers are so designed that a pipe can be withdrawn from the Economizer without chipping and destroying the pipes or headers as is the case in other constructions.

MANIFOLDS

At the top and back of the economizer is a manifold or top connecting chamber (Fig. B) for the different sections. The sections of these manifolds are connected by pipes which allow for expansion and contraction (Fig. E).

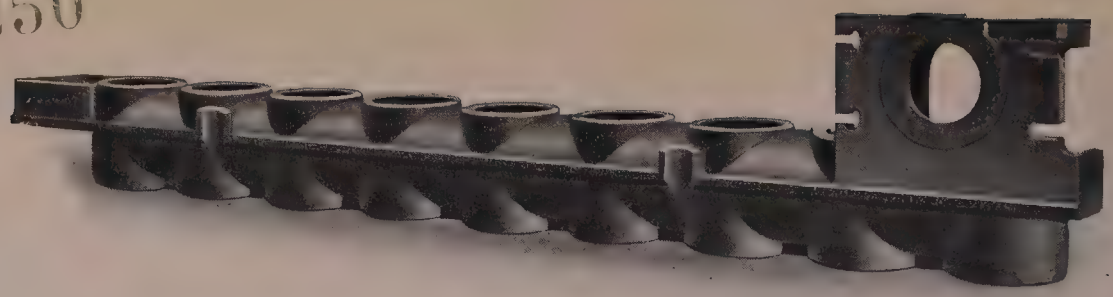
The wall box (Fig. C) is a connecting chamber for the different sections at the lower front of the economizer, and, like the manifold at the top, is in sections connected by "U" joints (Fig. G) to take care of any contraction and expansion. The wall box, as its name implies, rests on the foundation walls and distributes the weight of the economizer evenly on the foundations.

CONNECTIONS

Over the top of each economizer pipe in the top header is a cap (Fig. H) with a ground **metal-to-metal** joint so constructed that the greater

CAPS

Fig. G



TYPE OF TOP HEADERS USED IN OUR STANDARD ECONOMIZER ADAPTED TO PRESSURE UNDER 200 LBS.

SCRAPER GUARDS AND GUIDE

These guides operated by chains and gears (Fig. K) raise and lower scrapers (Fig. 1). Patented Guide Plate prevents stopping or binding

the pressure in the economizer the tighter the cap fits. In case it is necessary to remove one of the economizer pipes, this cap is taken off and the pipes removed as described on pages 22 and 23.

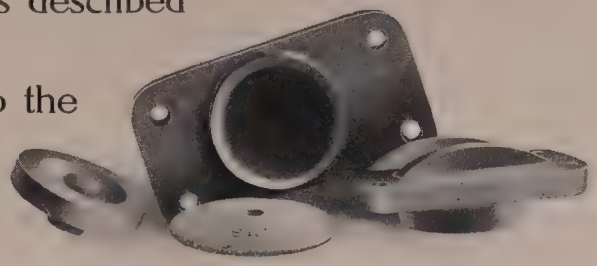


Fig. H

SCRAPERS

It is of great importance to keep the economizer pipes clean, as in any economizer a quantity of soot accumulates on the pipes preventing proper transmission of heat. We have overcome this objection by automatic pipe scrapers (Fig. I) which are moved up and down the pipes by a geared belt-driven mechanism (Fig. K) which acts positively and keeps the pipes clean. The soot drops to the bottom of the economizer and is readily removed through cleaning doors.

Fig. I

Note.—In the Sturtevant Economizer there is no danger of the scrapers stopping. This is an important point, because if the scrapers get stuck the pipes get soot-covered and will not properly transmit the heat to the feed water.

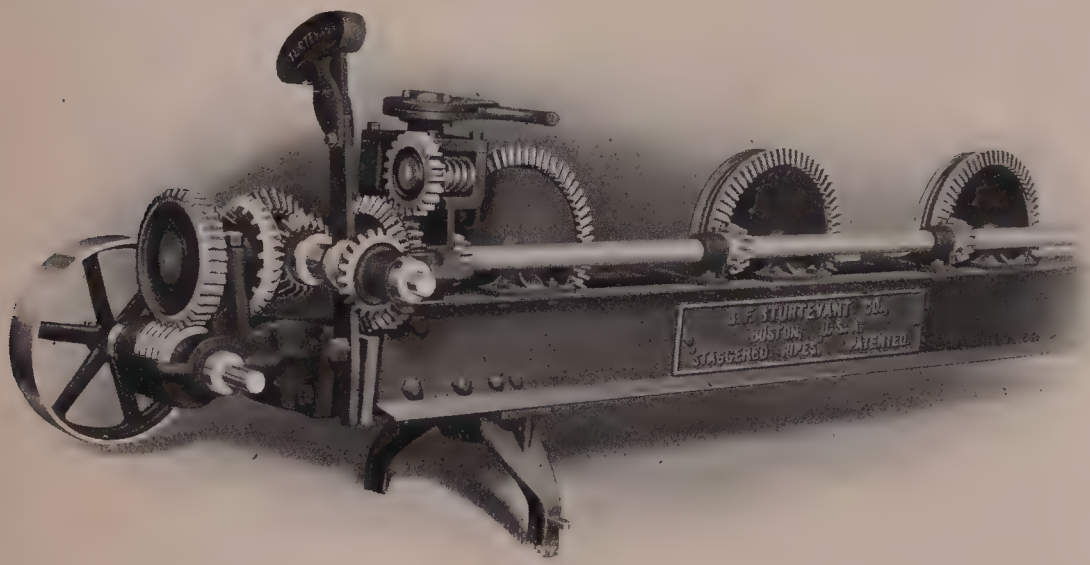
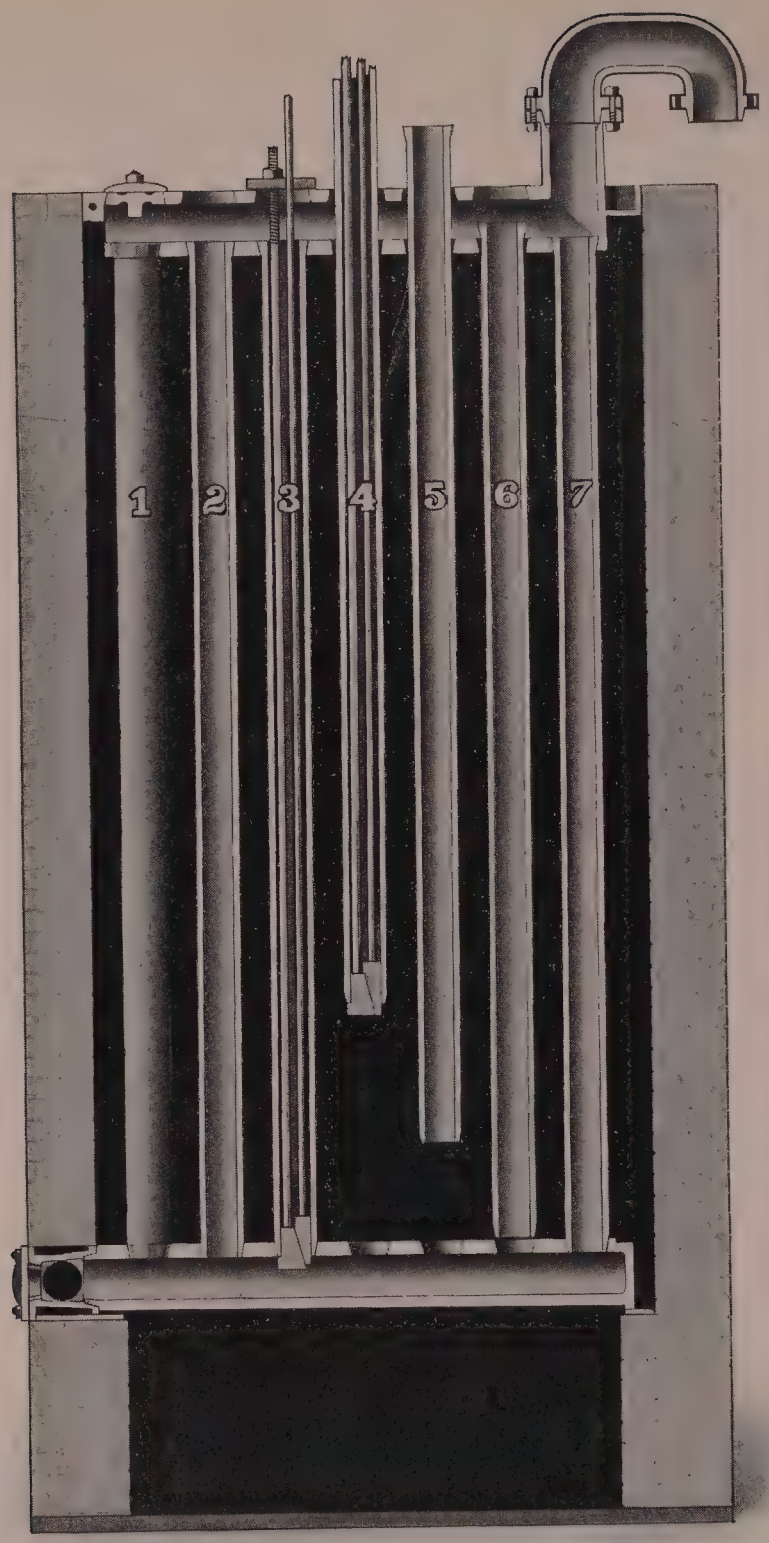


Fig. K



METHOD OF REMOVING PIPES FROM STURTEVANT ECONOMIZER

REPAIRING

Although our economizer is strongly constructed and repairs a small item, yet accidents must be provided for. The ease and simplicity of removing and replacing a pipe is a marked advantage of the Sturtevant Economizer; the whole operation requires but an hour. The **taper metal-to-metal** joints require no packing, cement, or rusting, there is no chipping or damaging the pipes or headers to get any one pipe out.

TAPER JOINTS

The taper joints at the top and bottom of the vertical pipes allow easy removal; when inserting a new pipe, tightness is secured by hammering it into good contact. Reference to the illustration on the opposite page will show how easily this substitution is effected.

Pipe No. 1 is in position with the inside cap in place at top.

Pipe No. 2 is a cross-section of pipe in position with cap removed.

Pipe No. 3 shows draw-out rods in place ready to start pipe from its friction joints. The rod at left with lower end shouldered to fit the pipe is first inserted and held at the top by the nut as shown. The right-hand rod at the same time is introduced as a wedge. By turning the nut on the left-hand rod, the friction joints are released.

Pipe No. 4 shows pipe removed from joints.

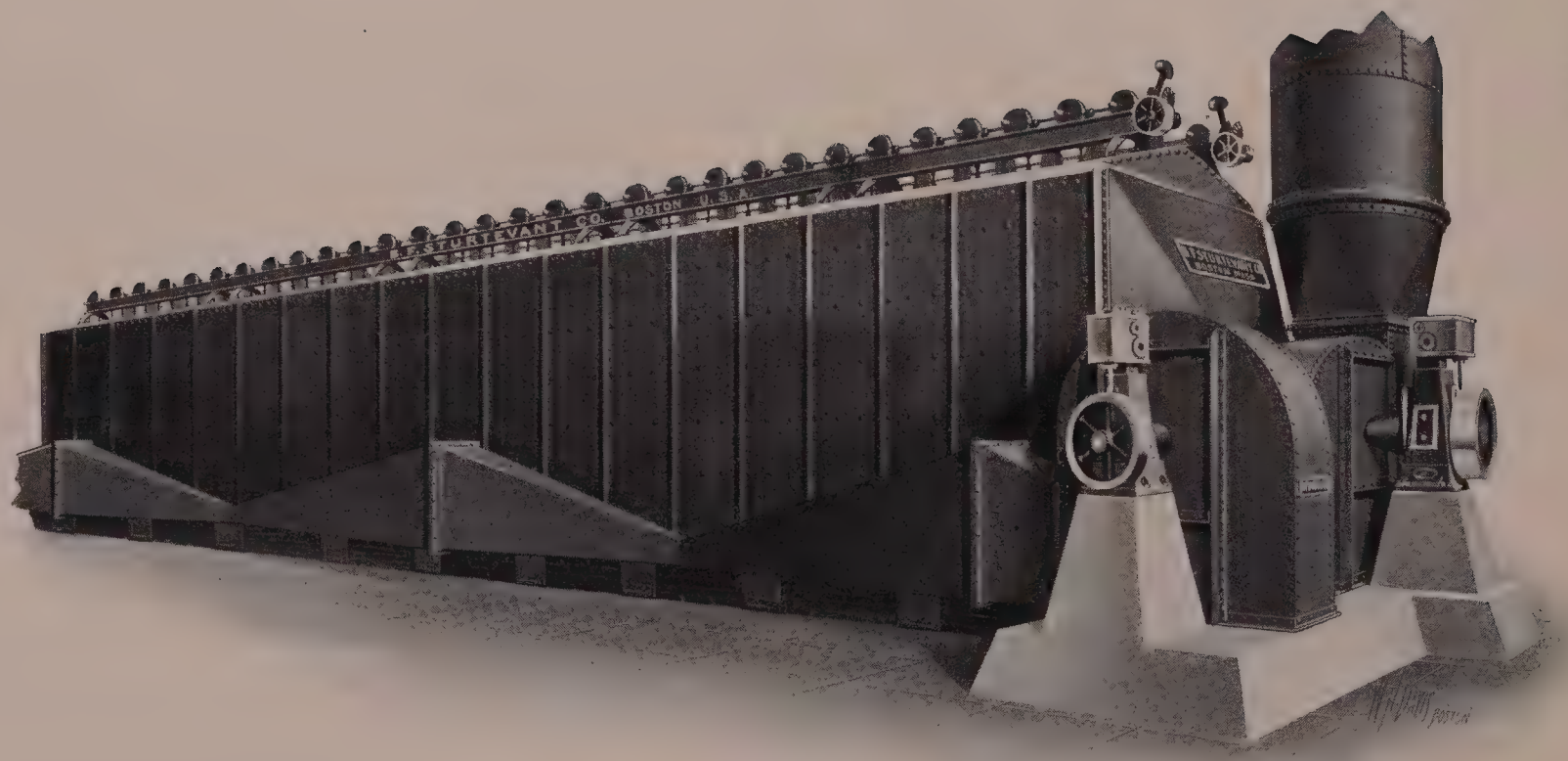
Pipe No. 5 shows the new pipe entering.

Pipe No. 6 is shown ready to enter the tapered seats.

Pipe No. 7 is the new pipe in place.

TOP AND BOTTOM HEADERS

The Top and Bottom Headers can be readily removed and duplicates inserted without disturbing the other headers, sections, or side walls. There are no branch pipes to take off or replace if a cap, pipe, or section is to be repaired. Any section can be taken out and a duplicate replaced without disturbing the other sections or the side walls. All water surfaces are readily accessible; the caps are the only parts to be removed when cleaning any of the water surfaces.



STURTEVANT AIR HEATER

THE STURTEVANT AIR HEATER

PURPOSE AND USES

For any purpose where extremely hot air, say a temperature of 300° F. or even higher, is desired, the Sturtevant Air Heater is about the only available means of obtaining this result. This system is used for plants doing special drying, baking, and tempering work, in textile mills, hospitals, and in any cases where a large volume of hot air is desired for drying purposes or for heating buildings, etc. It is particularly adapted for installation in laundries, where the regular economizer can be used as a hot water supply and a section of the economizer made as a hot air heater to supply hot air for drying the clothes.

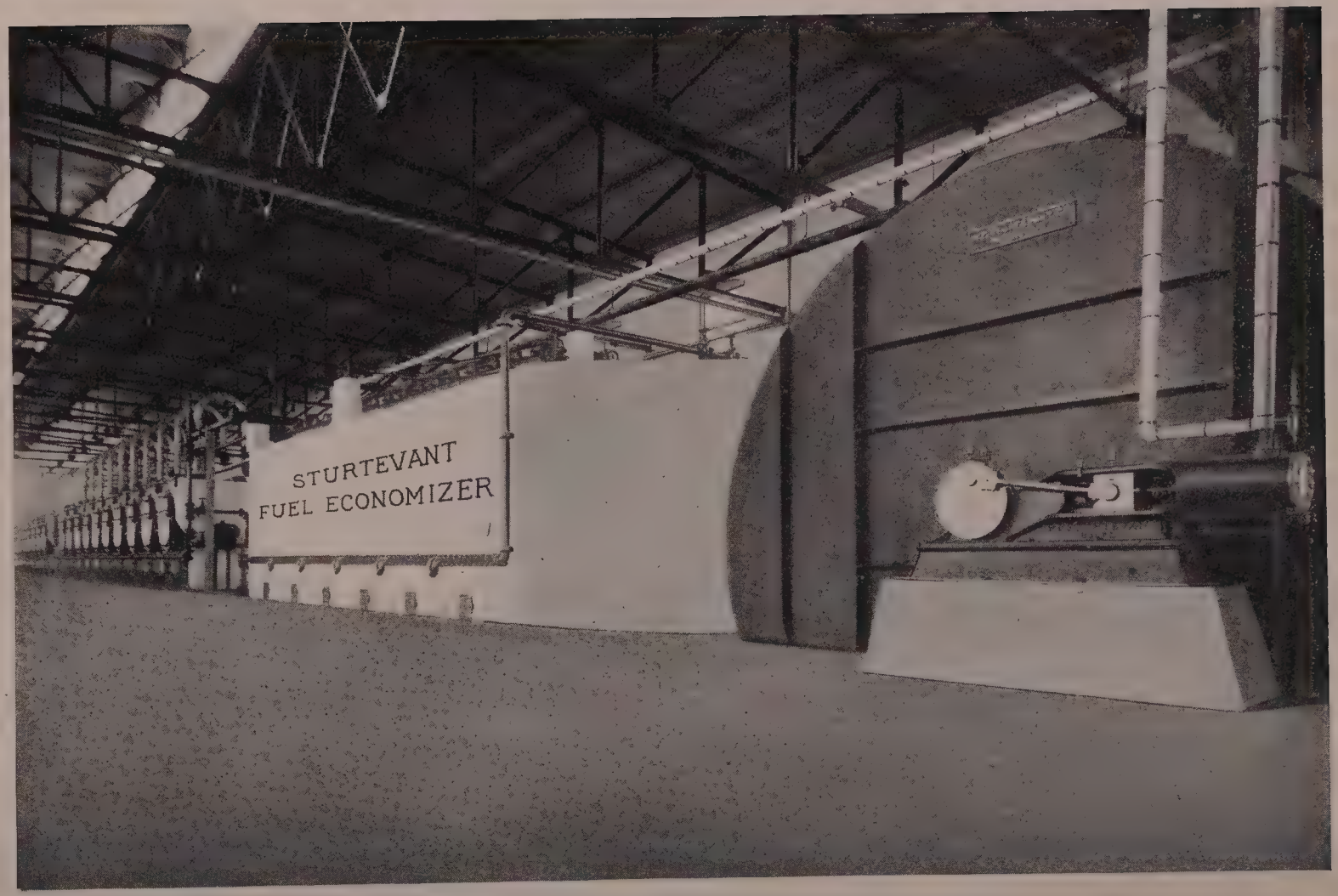
WORKING PRINCIPLE

The air heater is on the general principle of the fuel economizer previously described in this catalogue, except that through the economizer pipes air is forced instead of water, the hot gases from the boilers heating the air circulating in the economizer pipes instead of water as previously described.

CONSTRUCTION

In general construction the air heater is like the regular economizer, but there are a few points of special construction, as the headers which are of special form to distribute the proper volume of air to the different pipes. The air is forced through the heater by a fan system, as it is better to force air through the pipes rather than to draw it through by exhaust process. The circulation of the air is positive, being forced up and down a given number of sections depending on the volume, and in a course opposite to the direction of the hot gases, thereby obtaining greatest efficiency.

It is not practicable to receive the hot gases into air heaters at a temperature of over 800° or 900° F., as the cast-iron pipes, not being filled by water as in the case of a regular fuel economizer, are liable to be burned out by the excessive heat. It is always possible, however, to dilute any gases desired to be used, thus reducing them to the proper temperature.



ECONOMIZER AT THE WOOD WORSTED MILLS

MECHANICAL DRAFT

Mechanical Draft is produced by a centrifugal fan, and may be applied as Forced or Induced Draft, depending upon conditions. It does more than an ordinary chimney can do, and its cost is from 20 to 30 per cent of that of the chimney. The intensity of mechanical draft permits the burning of finely divided or low-grade fuel and makes possible the fullest utilizing of the hot flue gases which a chimney wastes in producing drafts. It is independent of the weather; is automatically regulated to maintain constant steam pressure; decreases smoke; increases the capacity of an existing plant, or serves as an auxiliary to a chimney already overburdened.

WHAT IT DOES

Forced Draft is particularly applicable to old plants in which increased capacity could otherwise be obtained only by installing more boilers, increasing the height of the chimney or building a new one. The air, under slight pressure from the fan, is forced through pipes or ducts and discharged into the ash pit through openings in its sides or bottom, thus giving a positive draft which can be regulated as desired.

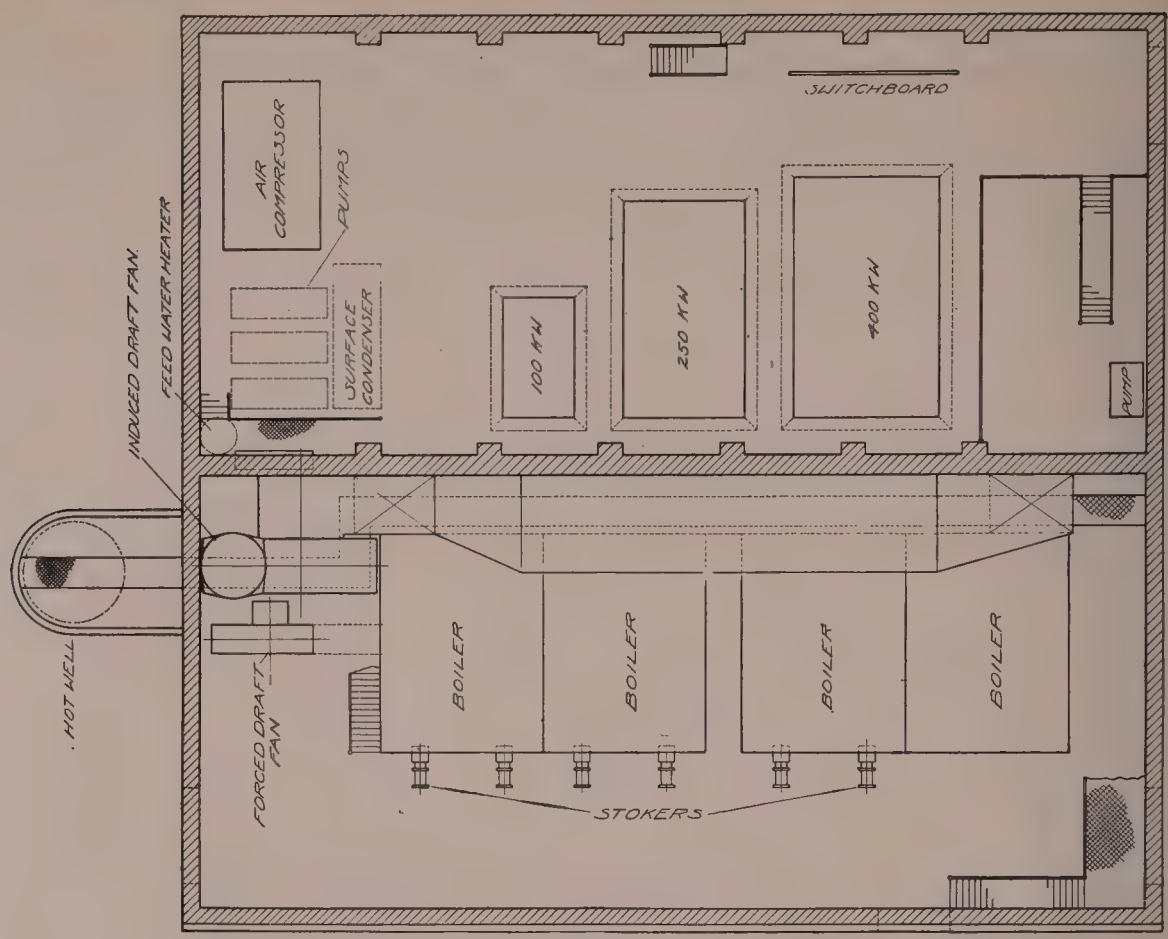
FORCED DRAFT

Induced Draft is so arranged that the gases, after leaving the boilers, are drawn through the fan and a partial vacuum maintained within the boiler furnace, which draws the air from the ash pits through the fire beds, giving a positive draft, regulated as desired. As a matter of convenience, the fan is ordinarily installed overhead where it occupies no valuable floor space, and discharges through a short stack extending just above the roof. The shaft runs in water-cooled journal boxes, so that hot gases can be handled without trouble.

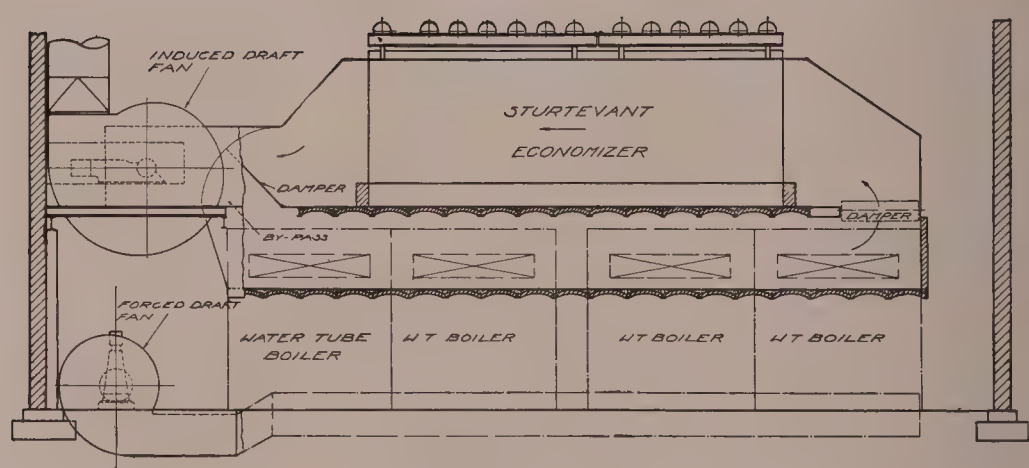
INDUCED DRAFT

Under either system, the fan is usually equipped with direct-connected engine, motor, or turbine automatically regulated to maintain constant steam pressure. The fan being directly driven permits operating the fan when the remainder of the plant is idle.

METHOD OF DRIVING



PLAN



ELEVATION

TYPICAL LAYOUT OF STURTEVANT ECONOMIZER WITH FORCED AND INDUCED DRAFT

ECONOMIZER WITH MECHANICAL DRAFT

The Sturtevant Economizer and Mechanical Draft each have their value in the operation of a steam plant, as previously shown in this catalogue, and may be successfully applied independently, but for maximum saving and increase of capacity both should be installed.

ADVANTAGES OF MECHANICAL DRAFT

In any plant the draft must be sufficiently strong, that is, have enough velocity for the air to pass through the fuel bed and supply sufficient oxygen for complete combustion. With natural draft the intensity depends largely upon the temperature of the gases entering the base of the chimney, and since the economizer reduces this temperature, such an installation may have its draft appreciably affected. With the fan blower the draft is entirely independent of the reduction of temperature; in fact, a lower temperature is an advantage, for the volume to be handled is less, therefore all heat possible may be taken from the gases. Although not a necessity when chimney draft is sufficient, yet mechanical draft is better than a chimney when the heat in the waste gases is to be utilized.

KIND OF DRAFT

The kind of draft to be used is always dependent upon the boiler plant itself. If the draft is insufficient, a fan should be added, and for more boiler capacity and greater fuel economy, both a fan and an economizer are advisable. An economizer without a fan should not be put into a plant having poor draft, but under any conditions the combination of an economizer and mechanical draft may be installed and result in a saving more than sufficient to warrant the investment.

ARRANGEMENT

The arrangement of economizers and fans depends upon the location of other apparatus in the plant, the only conditions necessary are that the waste gases pass through the economizer on their way to the chimney, and that the economizer should be placed near the boilers to prevent waste of heat from any unnecessarily long transmission.

SIZES STURTEVANT STANDARD ECONOMIZERS

Height over gearing, 12 ft. 6 in. Height over section, 10 ft, 2¼ in.

Machine Number.	Number of Pipes.	Number of Sections.	No. of Pipes in Section.	External Heating Surface. Sq. ft.	Capacity in Pounds of Water.	GENERAL DIMENSIONS.			
						Length ft. in.	Width with Stan'rd Back Side D'mp'rs ft. in.	AREA BETWEEN TUBES Without Side Dampers	With One Side Damper
1	32	8	4	400	2016	4—10	4—1	16.75	24.00
2	48	12	4	600	3024	7— 3	"	"	"
3	64	16	4	801	4032	9— 8	"	"	"
4	80	20	4	1001	5040	12— 1	"	"	"
5	96	24	4	1201	6048	14— 6	"	"	"
6	112	28	4	1401	7056	16—11	"	"	"
7	128	32	4	1601	8064	19— 4	"	"	"
8	40	8	5	499	2520	4—10	4—9	19.40	26.65
9	60	12	5	749	3780	7— 3	"	"	"
10	80	16	5	999	5040	9— 8	"	"	"
11	100	20	5	1248	6300	12— 1	"	"	"
12	120	24	5	1499	7560	14— 6	"	"	"
13	140	28	5	1747	8820	16—11	"	"	"
14	160	32	5	1997	10080	19— 4	"	"	"
15	180	36	5	2247	11340	21— 9	"	"	"
16	200	40	5	2496	12600	24— 2	"	"	"
17	72	12	6	897	4536	7— 3	5—5	22.00	29.30
18	96	16	6	1196	6048	9— 8	"	"	"
19	120	20	6	1496	7560	12— 1	"	"	"
20	144	24	6	1795	9072	14— 6	"	"	"
21	168	28	6	2094	10584	16—11	"	"	"
22	192	32	6	2393	12096	19— 4	"	"	"
23	216	36	6	2692	13608	21— 9	"	"	"
24	240	40	6	2991	15120	24— 2	"	"	"
25	264	44	6	3290	16632	26— 7	"	"	"
26	288	48	6	3589	18144	29— 0	"	"	"
27	112	16	7	1394	7056	9— 8	6—1	24.70	31.95
28	140	20	7	1743	8820	12— 1	"	"	"
29	168	24	7	2092	10584	14— 6	"	"	"
30	196	28	7	2440	12348	16—11	"	"	"
31	224	32	7	2789	14112	19— 4	"	"	"
32	252	36	7	3137	15876	21— 9	"	"	"
33	280	40	7	3486	17640	24— 2	"	"	"
34	308	44	7	3835	19404	26— 7	"	"	"
35	336	48	7	4183	21168	29— 0	"	"	"
36	364	52	7	4532	22932	31— 5	"	"	"
37	392	56	7	4880	24696	33—10	"	"	"
38	128	16	8	1592	8064	9— 8	6—9	27.35	34.60
39	160	20	8	1990	10080	12— 1	"	"	"
40	192	24	8	2388	12096	14— 6	"	"	"
41	224	28	8	2786	14112	16—11	"	"	"
42	256	32	8	3185	16128	19— 4	"	"	"
43	288	36	8	3583	18144	21— 9	"	"	"
44	320	40	8	3981	20160	24— 2	"	"	"
45	352	44	8	4379	22176	26— 7	"	"	"
46	384	48	8	4777	24182	29— 0	"	"	"
47	416	52	8	5175	26198	31— 5	"	"	"
48	448	56	8	5573	28224	33—10	"	"	"
49	480	60	8	5971	30240	36— 3	"	"	"

SIZES STURTEVANT STANDARD ECONOMIZERS

Height over gearing, 12 ft. 6 in. Height over section, 10 ft, 2¼ in.

Machine Number.	Number of Pipes.	Number of Sections.	No. of Pipes in Section.	External Heating Surface. Sq. ft.	Capacity in Pounds of Water.	GENERAL DIMENSIONS. Length ft. in.	Width with Stan'rd Back Side D'mpr's ft. in.	AREA BETWEEN TUBES Without Side Dampers	AREA BETWEEN TUBES With One Side Damper
50	180	20	9	2237	11340	12— 1	7—5	30.00	37.25
51	216	24	9	2685	13608	14— 6	"	"	"
52	252	28	9	3132	15876	16—11	"	"	"
53	288	32	9	3580	18144	19— 4	"	"	"
54	324	36	9	4027	20412	21— 9	"	"	"
55	360	40	9	4475	22680	24— 2	"	"	"
56	396	44	9	4922	24948	26— 7	"	"	"
57	432	48	9	5370	27216	29— 0	"	"	"
58	468	52	9	5817	29484	31— 5	"	"	"
59	504	56	9	6265	31752	33—10	"	"	"
60	540	60	9	6712	34020	36— 3	"	"	"
61	576	64	9	7160	36288	38— 8	"	"	"
62	200	20	10	2484	12600	12— 1	8—1	32.65	39.90
63	240	24	10	2981	15120	14— 6	"	"	"
64	280	28	10	3478	17640	16—11	"	"	"
65	320	32	10	3974	20160	19— 4	"	"	"
66	360	36	10	4471	22680	21— 9	"	"	"
67	400	40	10	4968	25200	24— 2	"	"	"
68	440	44	10	5465	27720	26— 7	"	"	"
69	480	48	10	5962	30240	29— 0	"	"	"
70	520	52	10	6458	32760	31— 5	"	"	"
71	560	56	10	6955	35280	33—10	"	"	"
72	600	60	10	7452	37800	36— 3	"	"	"
73	640	64	10	7949	40320	38— 8	"	"	"
74	680	68	10	8446	42840	41— 1	"	"	"
75	396	36	11	4915	24949	21— 9	8—9	35.30	42.55
76	440	40	11	5461	27720	24— 2	"	"	"
77	484	44	11	6008	30497	26— 7	"	"	"
78	528	48	11	6554	33268	29— 0	"	"	"
79	572	52	11	7101	36045	31— 5	"	"	"
80	616	56	11	7646	38811	33—10	"	"	"
81	660	60	11	8193	41588	36— 3	"	"	"
82	704	64	11	8739	44359	38— 8	"	"	"
83	748	68	11	9286	47136	41— 1	"	"	"
84	792	72	11	9832	49907	43— 6	"	"	"
85	836	76	11	10379	52684	45—11	"	"	"
86	880	80	11	10925	55455	48— 4	"	"	"
87	528	44	12	6549	33262	26— 7	9—5	37.95	45.20
88	576	48	12	7145	36289	29— 0	"	"	"
89	624	52	12	7741	39317	31— 5	"	"	"
90	672	56	12	8337	42344	33—10	"	"	"
91	720	60	12	8933	45371	36— 3	"	"	"
92	768	64	12	9529	48398	38— 8	"	"	"
93	816	68	12	10125	51425	41— 1	"	"	"
94	864	72	12	10721	54452	43— 6	"	"	"
95	912	76	12	11317	57479	45—11	"	"	"
96	960	80	12	11913	60506	48— 4	"	"	"
97	1008	84	12	12489	63432	50— 9	"	"	"
98	1056	88	12	13065	66357	53— 2	"	"	"

EXPLANATION OF TABLES

EFFICIENCY OF FUEL

The efficiency of any fuel is the amount of heat energy contained in it compared with an established standard which is the heat value of pure carbon, 14,650 British thermal units per pound. Thus, if coal gives out 10,250 B. T. U. per pound, it has an efficiency of 70 per cent. The proportion of this actually transmitted to the water depends upon the efficiency of the boiler. If the above mentioned coal is burned under a boiler having an efficiency of 65 per cent, $.65 \times 10{,}250 = 6662.5$ B. T. U. will be utilized; the combined efficiency of the boiler and coal will be $\frac{6662.5}{14650}$, or 45.5 per cent. Since 965.7 B. T. U. is the amount of heat necessary to convert one pound of water at 212° F. into steam at atmospheric pressure (see table of Properties of Saturated Steam), the standard fuel will evaporate $\frac{14{,}650}{965.7} = 15.2$ pounds of water. The coal under consideration will evaporate $\frac{6662.5}{965.7} = 6.9$ pounds of water. These principles are used in calculating the values in the table opposite.

PERCENTAGES GAINED

Knowing the temperature of the feed water before it enters an economizer and just as it leaves, the amount of heat imparted to it may be determined directly. If in addition the boiler pressure is considered, the percentage gained is easily calculated or found from the values given in the tables on succeeding pages. The formula for obtaining these values is:

$$\text{Gain in per cent} = \frac{100\,(T-t)}{H-t}$$

in which T = heat units in 1 pound of water above zero after heating,
t = heat units in one pound of water above zero before heating,
H = heat units in 1 pound of steam at boiler pressure above zero.

EFFICIENCY OF FUELS

British Thermal Units in One Pound of Fuel.	Water Evaporated from and at 212° per Pound of Fuel. Theoretical.	Efficiency of Fuel. Theoretical.	EFFICIENCY OF BOILER.									
			90 PER CENT.		80 PER CENT.		70 PER CENT.		60 PER CENT.		50 PER CENT.	
			Water Evaporated from and at 212° per Pound of Fuel.	Efficiency of Fuel.	Water Evaporated from and at 212° per Pound of Fuel.	Efficiency of Fuel.	Water Evaporated from and at 212° per Pound of Fuel.	Efficiency of Fuel.	Water Evaporated from and at 212° per Pound of Fuel	Efficiency of Fuel.	Water Evaporated from and at 212° per Pound of Fuel.	Efficiency of Fuel.
14,650	15.2	100.	13.6	90.0	12.1	80.0	10.6	70.0	9.1	60.0	7.6	50.0
14,500	15.0	99.0	13.5	89.0	12.0	79.2	10.5	69.3	9.0	59.4	7.5	49.5
14,250	14.8	97.3	13.3	87.6	11.8	77.8	10.3	68.1	8.9	58.4	7.4	48.7
14,000	14.5	95.6	13.0	86.0	11.6	76.5	10.1	66.9	8.7	57.4	7.3	47.8
13,750	14.2	93.9	12.8	84.5	11.4	75.1	10.0	65.7	8.6	56.3	7.1	47.0
13,500	14.0	92.2	12.6	83.0	11.2	73.8	9.8	64.5	8.4	55.3	7.0	46.1
13,250	13.7	90.5	12.3	81.5	11.0	72.4	9.6	63.4	8.3	54.3	6.9	45.3
13,000	13.5	88.8	12.1	79.9	10.8	71.0	9.4	62.2	8.1	53.3	6.7	44.4
12,750	13.2	87.1	11.9	78.4	10.5	69.7	9.2	61.0	7.9	52.3	6.6	48.6
12,500	12.9	85.4	11.6	76.9	10.3	68.3	9.0	59.8	7.7	51.2	6.5	42.7
12,250	12.7	83.7	11.4	75.3	10.1	67.0	8.9	58.6	7.6	50.2	6.4	41.9
12,000	12.4	82.0	11.2	73.8	9.9	65.6	8.7	57.4	7.5	49.2	6.2	41.0
11,750	12.2	80.3	11.0	72.3	9.7	64.2	8.5	56.2	7.3	48.2	6.1	40.2
11,500	11.9	78.6	10.8	70.7	9.6	62.9	8.4	55.0	7.1	47.2	6.0	39.3
11,250	11.7	76.9	10.5	69.2	9.3	61.5	8.2	53.8	7.0	46.1	5.9	38.5
11,000	11.4	75.2	10.2	67.7	9.1	60.2	8.0	52.6	6.8	45.1	5.7	37.6
10,750	11.1	73.5	10.0	66.2	8.9	58.8	7.8	51.5	6.7	44.1	5.6	36.8
10,500	10.9	71.8	9.8	64.6	8.7	57.4	7.6	50.3	6.5	43.1	5.4	35.9
10,250	10.6	70.0	9.5	63.0	8.5	56.0	7.4	49.1	6.4	42.0	5.3	35.0
10,000	10.4	68.3	9.3	61.5	8.3	54.7	7.2	47.8	6.3	41.0	5.2	34.2
9,750	10.1	66.6	9.1	59.9	8.1	53.3	7.1	46.6	6.1	40.0	5.1	33.3
9,500	9.8	64.9	8.8	58.4	7.9	51.9	6.9	45.4	5.9	38.9	4.9	32.5
9,250	9.6	63.2	8.6	56.9	7.7	50.6	6.7	44.2	5.7	37.9	4.8	31.6
9,000	9.3	61.4	8.4	55.3	7.5	49.1	6.5	43.0	5.6	36.8	4.7	30.7
8,750	9.1	59.7	8.2	53.7	7.3	47.8	6.3	41.8	5.4	35.8	4.6	29.8
8,500	8.8	58.0	7.9	52.2	7.0	46.4	6.2	40.6	5.3	34.8	4.4	29.0

PROPERTIES OF SATURATED STEAM

Total Pressure, in lbs. per Sq. In., Measured from a Vacuum	Temperature, in Degrees Fahrenheit of Steam and of the Water from which it Was Evaporated	Number of British Thermal Units Contained in One Pound Reckoned from Zero Fahrenheit		Weight of One Cubic Foot of Steam, in Decimals of a Pound	Volume of One Pound of Steam, in Cubic Feet	Relative Volume or Cubic Feet of Steam from one Cubic Foot of Water
		Number Required for Evaporation, Known as Latent Heat, or Heat of Vaporization	Total Number Contained in the Steam			
1	101.84	1034.7	1136.5	.0030	333.10	20750.0
2	126.15	1021.9	1148.1	.0057	173.10	10790.0
3	141.52	1012.2	1153.8	.0084	118.40	7380.0
4	153.00	1005.5	1158.5	.0110	90.40	5630.0
5	162.26	1000.0	1162.3	.0136	73.30	4570.0
6	170.07	995.5	1165.6	.0161	61.90	5855.0
7	176.84	991.4	1168.3	.0186	53.60	3340.0
8	182.86	987.8	1170.7	.0211	47.26	2942.0
9	188.27	984.5	1172.9	.0236	42.36	2640.0
10	193.21	981.4	1174.7	.0260	38.37	2390.0
12	201.95	976.0	1178.1	.0308	32.40	2020.0
14	209.55	971.2	1181.0	.0356	28.03	1746.0
14.7	212.00	965.7	1178.6	.0380	26.36	1644.0
16	216.31	967.0	1183.6	.0404	24.74	1541.0
18	222.40	963.1	1185.9	.0451	22.17	1380.0
20	222.95	959.4	1187.8	.0497	20.09	1250.0
22	233.07	956.0	1189.6	.0544	18.37	1144.0
24	237.82	952.9	1191.3	.0591	16.92	1054.0
26	242.26	949.9	1192.8	.0637	15.70	979.0
28	246.41	947.1	1194.2	.0682	14.67	915.0
30	250.34	944.4	1195.5	.0728	13.74	856.5
32	254.05	941.8	1196.7	.0773	12.93	805.5
34	257.59	939.4	1197.9	.0819	12.21	761.5
36	260.96	937.1	1199.0	.0864	11.58	722.4
38	264.17	934.8	1200.0	.0908	11.01	686.5
40	267.26	932.6	1201.0	.0953	10.47	654.0
42	270.23	930.6	1202.0	.0998	10.02	625.0
44	273.07	928.5	1202.8	.1043	9.589	597.5
46	275.82	926.6	1203.7	.1087	9.195	572.6
48	278.47	924.7	1204.5	.1131	8.838	550.0
50	281.03	922.8	1205.2	.1176	8.507	530.3
52	283.52	921.0	1206.0	.1220	8.198	510.0
54	285.93	919.3	1206.7	.1264	7.912	492.7
56	288.25	917.6	1207.4	.1308	7.647	476.0
58	290.53	915.9	1208.0	.1352	7.397	460.5

PROPERTIES OF SATURATED STEAM—[Concluded

Total Pressure, in lbs. per Sq. In.,	Temperature, in Degrees Fahrenheit of Steam, etc.	Number of B.T.U., etc.		Weight of One Cubic Foot of Steam, etc.	Volume of One Pound of Steam, in Cubic Feet	Relative Volume or Cubic Feet Steam, etc.
		Number Required for Evaporation	Total Number Contained, etc.			
60	292.74	914.3	1208.7	.1395	7.166	446.5
62	294.88	912.7	1209.3	.1439	6.949	432.5
64	296.97	911.1	1209.8	.1483	6.745	420.0
66	299.02	909.6	1210.4	.1526	6.552	408.0
68	301.01	908.1	1211.0	.1570	6.370	397.0
70	302.96	906.6	1211.5	.1613	6.199	388.0
72	304.86	905.2	1212.0	.1657	6.036	376.0
74	306.72	903.8	1212.5	.1700	5.882	366.8
76	308.54	902.4	1213.0	.1744	5.735	357.4
78	310.33	901.1	1213.5	.1787	5.597	348.5
80	312.08	899.8	1214.0	.1829	5.466	340.5
82	313.79	898.5	1214.4	.1872	5.342	332.8
84	315.47	897.2	1214.9	.1916	5.220	324.7
86	317.12	895.9	1215.3	.1959	5.104	318.0
88	318.73	894.7	1215.7	.2003	4.993	311.3
90	320.32	893.5	1216.2	.2047	4.886	304.5
92	321.88	892.3	1216.6	.2090	4.785	278.2
94	323.41	891.1	1217.0	.2133	4.689	292.0
96	324.91	889.9	1217.3	.2174	4.599	286.4
98	326.40	888.7	1217.6	.2215	4.514	281.0
100	327.86	887.6	1218.1	.2256	4.432	276.2
110	334.83	882.1	1219.7	.2471	4.047	252.0
120	341.31	876.9	1221.2	.2686	3.723	232.0
130	347.38	872.1	1222.7	.2898	3.451	215.0
140	353.09	867.4	1223.8	.3106	3.220	200.8
150	358.50	863.0	1225.0	.3318	3.014	187.9
160	363.62	858.8	1226.1	.3528	2.834	176.7
170	368.50	854.8	1227.2	.3741	2.673	166.5
180	373.16	850.9	1237.1	.3951	2.531	157.7
190	377.61	847.1	1228.9	.4158	2.405	149.8
200	381.89	843.5	1229.8	.4371	2.288	142.6
215	388.02	838.3	1230.9	.4682	2.136	133.0
230	393.80	833.3	1231.9	.4997	2.001	124.8
245	399.32	828.5	1232.9	.5310	1.882	117.3
260	404.55	823.9	1233.7	.5630	1.775	110.6
275	409.57	819.5	1234.6	.5950	1.681	104.8
290	414.35	815.2	1235.3	.6270	1.595	99.5
305	418.97	811.1	1236.0	.6590	1.517	94.6
320	423.40	807.1	1236.6	.6920	1.446	90.1
335	427.67	803.2	1237.2	.7240	1.381	86.2

PERCENTAGE OF SAVING EFFECTED PER DEGREE INCREASE IN FEED WATER

FEED WATER TEMP. F°	BOILER PRESSURE AS SHOWN BY GAUGE												
	85	90	95	100	110	120	130	140	150	160	170	180	200
32	.0846	.0845	.0845	.0844	.0842	.0841	.0840	.0839	.0838	.0837	.0836	.0835	.0833
35	.0848	.0848	.0847	.0846	.0845	.0843	.0842	.0841	.0840	.0840	.0838	.0837	.0836
40	.0852	.0851	.0850	.0850	.0848	.0847	.0846	.0845	.0843	.0843	.0841	.0841	.0839
45	.0855	.0855	.0854	.0853	.0852	.0851	.0849	.0848	.0847	.0846	.0845	.0844	.0843
50	.0859	.0858	.0858	.0857	.0855	.0854	.0853	.0852	.0851	.0850	.0849	.0848	.0846
55	.0863	.0862	.0861	.0861	.0859	.0858	.0857	.0855	.0854	.0853	.0852	.0851	.0850
60	.0867	.0866	.0865	.0864	.0863	.0862	.0860	.0859	.0858	.0856	.0856	.0855	.0853
65	.0870	.0870	.0869	.0868	.0867	.0865	.0864	.0863	.0862	.0861	.0860	.0859	.0858
70	.0874	.0874	.0873	.0872	.0870	.0869	.0868	.0867	.0865	.0864	.0863	.0862	.0860
75	.0878	.0877	.0876	.0876	.0874	.0873	.0872	.0870	.0869	.0868	.0867	.0866	.0865
80	.0882	.0882	.0880	.0879	.0878	.0877	.0875	.0874	.0873	.0872	.0871	.0870	.0868
85	.0886	.0885	.0884	.0883	.0882	.0880	.0879	.0878	.0877	.0876	.0875	.0874	.0873
90	.0890	.0889	.0888	.0887	.0886	.0884	.0883	.0883	.0881	.0879	.0878	.0877	.0875
95	.0894	.0893	.0892	.0891	.0890	.0888	.0887	.0886	.0884	.0883	.0882	.0881	.0880
100	.0898	.0897	.0896	.0895	.0894	.0892	.0891	.0890	.0888	.0887	.0886	.0885	.0883
105	.0902	.0901	.0900	.0899	.0898	.0896	.0895	.0894	.0892	.0891	.0891	.0889	.0888
110	.0906	.0905	.0904	.0903	.0902	.0900	.0897	.0898	.0896	.0895	.0894	.0893	.0891
115	.0910	.0909	.0908	.0907	.0906	.0904	.0903	.0902	.0900	.0899	.0898	.0897	.0896
120	.0914	.0913	.0912	.0911	.0910	.0908	.0907	.0906	.0904	.0903	.0902	.0901	.0899
125	.0918	.0918	.0917	.0916	.0914	.0913	.0911	.0908	.0909	.0907	.0906	.0905	.0904
130	.0923	.0922	.0921	.0920	.0918	.0917	.0915	.0914	.0913	.0912	.0910	.0909	.0907
135	.0927	.0926	.0925	.0924	.0923	.0921	.0920	.0918	.0917	.0916	.0915	.0914	.0912
140	.0931	.0930	.0929	.0929	.0927	.0925	.0924	.0923	.0921	.0920	.0919	.0918	.0916
145	.0936	.0935	.0934	.0933	.0932	.0930	.0928	.0927	.0926	.0924	0923	.0922	.0922
150	.0940	.0939	.0939	.0937	.0936	.0934	.0933	.0931	.0930	.0929	.0927	.0926	.0924
155	.0945	.0944	.0943	.0942	.0940	0939	.0937	.0936	.0934	.0933	.0932	.0931	.0929
160	.0949	.0948	.0947	.0946	.0945	.0943	.0942	.0940	.0939	.0937	.0936	.0935	.0933
165	.0954	.0953	.0952	.0951	.0949	.0948	.0946	.0945	.0943	.0942	.0941	.0939	.0939
170	.0958	.0957	.0956	.0955	.0954	.0952	.0951	.0949	.0948	.0946	.0945	.0944	.0941
175	.0963	.0962	.0961	.0960	.0958	.0957	.0955	.0954	.0952	.0951	.0950	.0948	.0946
180	.0968	.0968	.0966	.0965	.0963	.0961	.0960	.0958	.0957	.0955	.0954	.0953	.0951
185	.0972	.0971	.0970	.0969	.0967	.0966	.0964	.0963	.0961	.0960	.0959	.0958	.0956
190	.0977	.0976	.0975	.0974	.0972	.0971	.0969	.0968	.0966	.0964	.0963	.0962	.0960
195	.0982	.0981	.0980	.0979	.0977	.0976	.0974	.0972	.0971	.0970	.0968	.0967	.0965
200	.0988	.0986	.0985	.0984	.0982	.0980	.0979	.0977	.0976	.0974	.0973	.0972	.0969
205	.0992	.0991	.0990	.0989	.0987	.0985	.0983	.0982	.0980	.0979	.0978	.0976	.0975
210	.0997	.0996	.0995	.0994	.0992	.0990	.0988	.0987	.0985	.0984	.0983	.0981	.0979
212	.0999	.0998	.0997	.0996	.0994	.0992	.0990	.0989	.0987	.0986	.0985	.0983	.0981
215	.1001	.1000	.1000	.0999	.0996	.0995	.0993	.0992	.0990	.0989	.0987	.0986	.0984

PERCENTAGE OF SAVING EFFECTED BY HEATING FEED WATER FROM INITIAL TO FINAL TEMPERATURE

BOILER GAUGE PRESSURE 100 POUNDS

Initial Temp'ture	FINAL TEMPERATURE OF WATER															
	100	120	140	160	180	200	210	220	230	240	250	260	270	280	290	300
60	3.5	5.2	6.9	8.6	10.4	12.1	13.0	13.8	14.7	15.5	16.4	17.3	18.1	19.0	19.8	20.7
80	1.7	3.5	5.2	7.0	8.8	10 5	11.4	12.3	13.2	14.0	14.9	15.8	16.7	17.5	18.4	19.3
100	—	1.8	3.6	5.4	7.1	8.9	9.8	10.7	11.6	12.5	13.4	14.3	15.2	16.1	17.0	17.9
110	—	0.9	2.7	4.5	6.3	8.1	9.0	9.9	10.8	11.7	12.6	13.5	14.4	15.3	16.2	17.1
120	—	—	1.8	3.6	5.5	7.3	8.2	9.1	10.0	10.9	11.8	12.7	13.6	14.5	15.5	16.4
130	—	—	0.9	2.8	4.6	6.9	7.4	8.3	9.2	10.1	11.0	11.9	12.8	13.8	14.7	15.6
140	—	—	—	1.9	3.7	5.6	6.5	7.4	8.4	9.3	10.2	11.1	12.1	13.0	13.9	14.9
150	—	—	—	0.9	2.8	4.7	5.6	6.6	7.5	8.4	9.4	10.3	11.2	12.2	13.1	14.0
160	—	—	—	—	1.9	3.8	4.7	5.7	6.6	7.6	8.5	9.5	10.4	11.4	12.3	13.2
170	—	—	—	—	1.0	2.9	3.8	4.8	5.7	6.7	7.6	8.6	9.5	10.5	11.5	12.4
180	—	—	—	—	—	1.9	2.9	3.9	4.8	5.8	6.8	7.7	8.7	9.7	10.6	11.6
190	—	—	—	—	—	1.0	1.9	2.9	3.9	4.9	5.8	6.8	7.8	8.8	9.7	10.7
200	—	—	—	—	—	—	1.0	2.0	3.0	3.9	4.9	5.9	6.9	7.9	8.9	9.8
205	—	—	—	—	—	—	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5
210	—	—	—	—	—	—	—	0.9	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0

Note.—The above table is very conservative.

INFLUENCE OF TEMPERATURE UPON CHIMNEY DRAFT

Changes in temperature, of the external atmosphere or the gases in the chimney, have a great influence on the draft, as shown in the table below, in which the draft, indicated in inches of water, is given for a chimney 100 feet high with various internal and external temperatures. For other heights of chimney the height of the water column is directly proportional to that of the chimney, hence doubling the height doubles the draft. The velocity which the draft creates and the corresponding volume of air moved vary as the square root of the height. This table indicates the need of high chimney temperatures for ample draft, and explains the stronger draft which exists in cold weather because of the greater temperature difference.

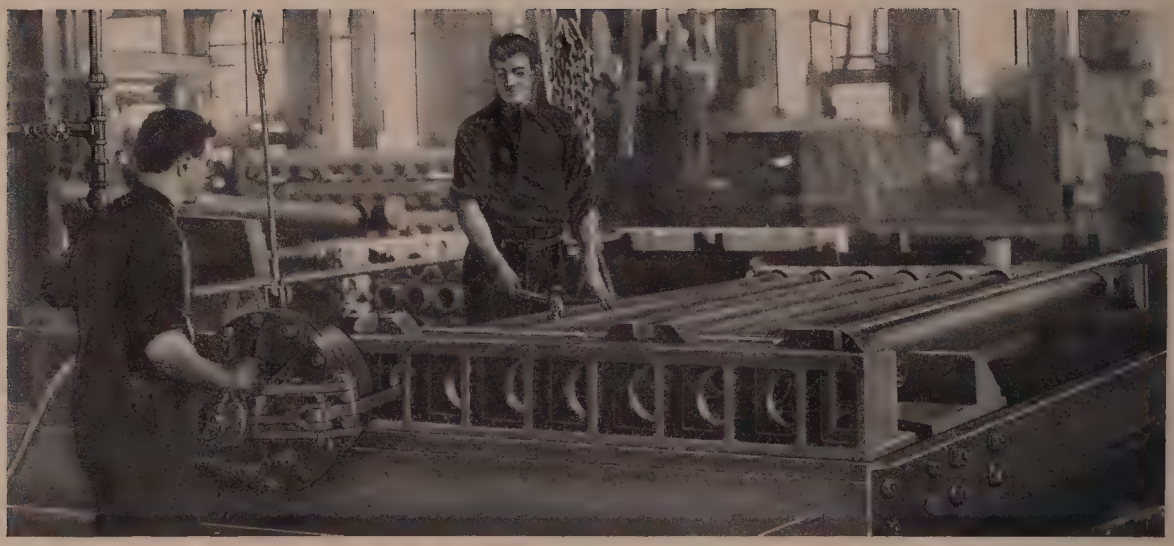
HEIGHT OF WATER COLUMN DUE TO UNBALANCED PRESSURES IN CHIMNEY 100 FEET HIGH

Temperature in Chimney.	Temperature of External Air. (Barometer 14.7 lbs.)										
	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°
200°	.453	.419	.384	.353	.321	.292	.263	.234	.209	.182	.157
220	.488	.453	.419	.388	.355	.326	.298	.269	.244	.217	.192
240	.520	.488	.451	.421	.388	.359	.330	.301	.276	.250	.225
260	.555	.528	.484	.453	.420	.392	.363	.334	.309	.282	.257
280	.584	.549	.515	.482	.451	.422	.394	.365	.340	.313	.288
300	.611	.576	.541	.511	.478	.449	.420	.392	.367	.340	.315
320	.637	.603	.568	.538	.505	.476	.447	.419	.394	.367	.342
340	.662	.638	.593	.563	.530	.501	.472	.443	.419	.392	.367
360	.687	.653	.618	.588	.555	.526	.497	.468	.444	.417	.392
380	.710	.676	.641	.611	.578	.549	.520	.492	.467	.440	.415
400	.732	.697	.662	.632	.598	.570	.541	.513	.488	.461	.436
420	.753	.718	.684	.653	.620	.591	.563	.534	.509	.482	.457
440	.774	.739	.705	.674	.641	.612	.584	.555	.530	.503	.478
460	.793	.758	.724	.694	.660	.632	.603	.574	.549	.522	.497
480	.810	.776	.741	.710	.678	.649	.620	.591	.566	.540	.515
500	.829	.791	.760	.730	.697	.669	.639	.610	.586	.559	.534

CAPACITY OF CHIMNEYS—KENT'S FORMULA

Dia. in Inches	HEIGHT OF CHIMNEY IN FEET																									Dia. in Inches
	100	105	110	115	120	125	130	135	140	145	150	155	160	165	170	175	180	185	190	195	200	225	250	275	300	
	COMMERCIAL HORSE POWER																									
48	348	356	365	373	381	389	396																			48
54	449	461	472	482	493	503	513	523	532	542																54
60	565	579	593	606	619	632	644	657	669	680	692	704	715													60
66	694	711	728	744	760	776	791	806	821	835	849	864	877	891	904	918										66
72	835	856	876	896	913	934	952	970	988	1006	1023	1040	1056	1073	1089	1105	1120	1136	1151							72
78		1014	1038	1062	1084	1107	1129	1150	1171	1192	1212	1232	1252	1272	1291	1310	1328	1346	1364	1382	1400	1485				78
84			1214	1241	1268	1294	1320	1345	1370	1394	1418	1441	1464	1487	1509	1531	1553	1574	1595	1616	1637	1736	1830	1919	2005	84
90				1435	1466	1496	1526	1555	1584	1612	1639	1666	1693	1719	1745	1771	1795	1820	1845	1869	1893	2008	2116	2217	2318	90
96				1643	1678	1713	1747	1780	1813	1845	1876	1907	1938	1968	1998	2027	2056	2084	2112	2140	2167	2298	2423	2542	2654	96
102					1905	1944	1983	2021	2058	2094	2130	2165	2200	2234	2268	2301	2333	2366	2397	2429	2459	2609	2750	2884	3012	102
108						2190	2234	2276	2318	2359	2399	2439	2478	2516	2554	2592	2628	2664	2700	2736	2771	2939	3098	3248	3393	108
114							2499	2547	2594	2640	2685	2729	2773	2816	2858	2900	2941	2982	3022	3061	3100	3288	3466	3635	3797	114
120								2833	2885	2936	2986	3036	3084	3132	3179	3226	3271	3316	3361	3405	3448	3657	3855	4040	4223	120
126									3191	3248	3305	3359	3412	3465	3618	3568	3620	3670	3720	3770	3818	4048	4268	4473	4672	126
132										3576	3637	3697	3756	3815	3872	3929	3984	4039	4093	4147	4200	4455	4696	4926	5144	132
138											3822	3885	3947	4009	4068	4127	4188	4243	4300	4357	4414	4680	4935	5178	5407	138
144												4424	4495	4565	4632	4701	4768	4834	4899	4963	5026	5331	5618	5892	6155	144
156													5300	5381	5465	5545	5625	5700	5780	5850	5925	6282	6622	6950	7260	156
168														6270	6365	6458	6550	6640	6725	6815	6900	7320	7720	8090	8450	168
180															7330	7440	7540	7645	7750	7850	7950	8430	8890	9320	9740	180

TESTING ASSEMBLED SECTION WITH HYDRAULIC PRESSURE



FORCING PIPES INTO HEADERS BY HYDRAULIC PRESSURE

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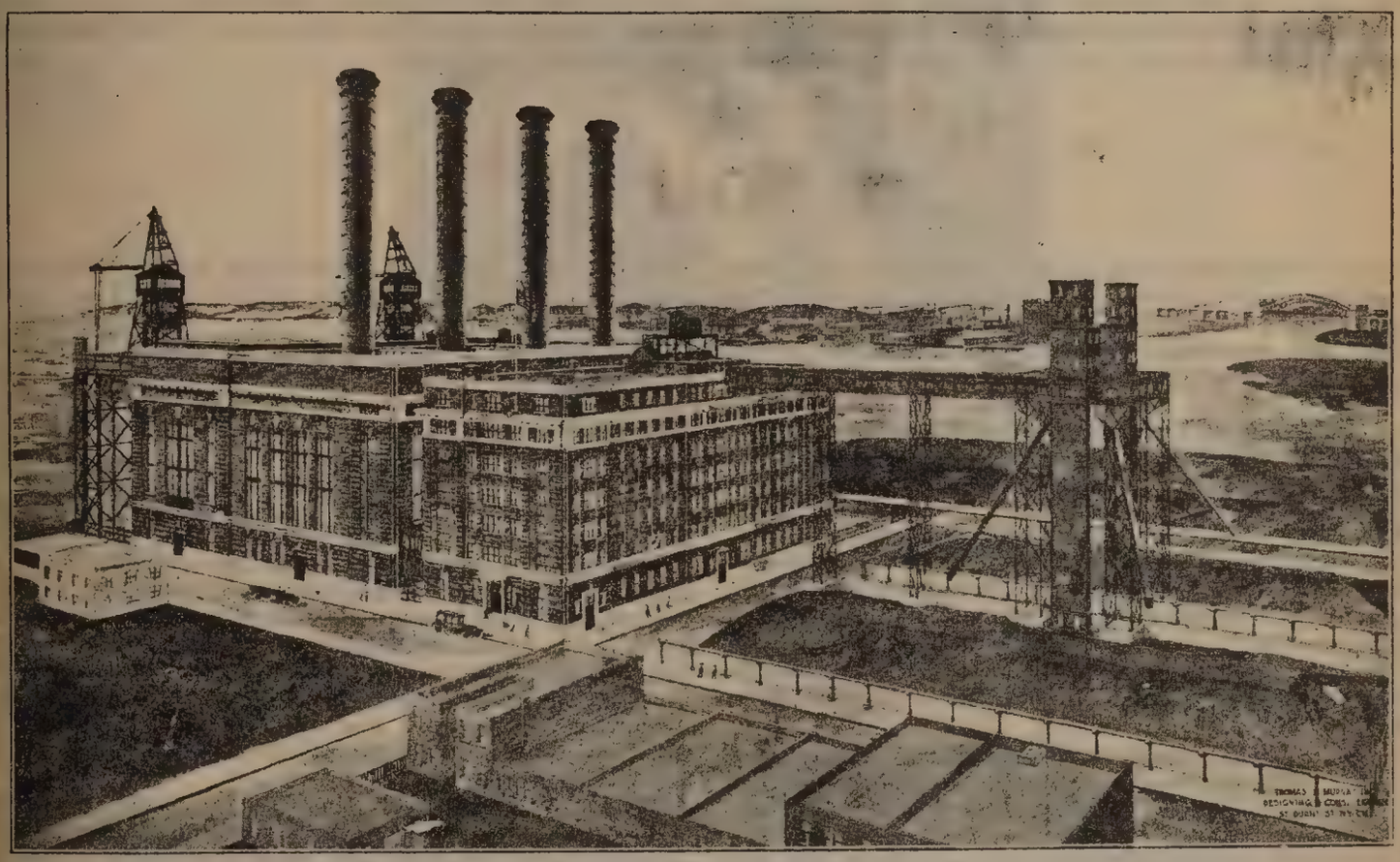
Plaintiff's Exhibit 10.

FOSTER NEWS

"Better Thru Understanding"



HELL GATE STATION—THE UNITED ELECTRIC LIGHT & POWER COMPANY
New York City

POWER SPECIALTY COMPANY

111 BROADWAY NEW YORK

Vol. 2, No. 9 June-July 1924

EXECUTIVE EDITORIAL

We have experienced during the last few months an almost unprecedented percentage of dark skies. The business also has had its dark skies, but the clouds are breaking away. The darkest cloud of the business sky has definitely passed away until next December—I refer to our Federal Congress, and I want to impress upon you the fact that you can do no work which will be of greater benefit to our business than to put forth an earnest effort to assist in removing from our Congress all those who are incompetent, inefficient, and who are selfishly working only for their own personal advantage and replace them with honest, fearless, intelligent men, such as we could select to manage our own business.

While business has, during the last few months, been somewhat depressed it is already showing marked signs of improvement, and with the National Conventions behind us, we may expect still further improvement without waiting for the Fall Elections. I know of nothing which any member of our organization can do which will be of greater benefit to our corporation than to work energetically for more capable, efficient, and loyal men in our Government. No individual working alone can accomplish anything, but by joining with other organizations, working for the same end, we can accomplish the result of having really representative men to run our country. I therefore urge upon each voter in the organization to set aside a definite amount of his time each week for this purpose.

ITALY

April twenty-first was a general holiday all over Italy, the most complete of the whole year, and corresponding quite closely to our Fourth of July and Labor Day combined. It happened to fall on Easter Monday, but was known officially as Rome's 2,678th birthday. Was it by chance that the founders of Rome chose a site which was to stand the test of ages? Or, was it the intelligence and sturdy qualities of the founders and their successors which has made their city so everlasting? A correct answer would probably give credence to both suggestions, for Italy possesses many natural advantages. The climate is good and varied. There are mountains and hills and plains. The land is fertile and there are rivers, but it is probably due to Italy's enormous coast line and the accessibility of all sections by water that her commerce has enjoyed such continued prosperity.

Italy's past is a matter of history, but what of her future? The favorable signs are in the orderliness of the people, their industry, and, above all, their patriotism. Yesterday, the national holiday was celebrated by labor festivals,—no red flags, but the national standard displayed everywhere. Mussolini is at the head of the government by virtue of his stand in favor of patriotism and the rights of private citizens at a time when those rights were seriously menaced by bolshevist agents posing as labor leaders.

The success of the Fascisti movement is Italy's message to the world to-day. She has shown the way to others by which a menacing situation may be completely saved by a small band of determined men possessing intelligence, high principles, courage, determination, and, above all, good leadership.

Everyone ought to read the history of this movement. It covers in all a period less than three years. It began in a small way with the conviction of a man of socialistic tendencies and a blacksmith by trade, that Italy was on the road to ruin, and that everything must be done to save her. He was a good speaker, and made his appeals on the ground of patriotism. The movement gained ground like the proverbial snow ball, and in scarcely more than a year Signor Mussolini found himself at the head of the government.

That the situation is likely to be stable for some time to come is indicated by the result of the recent elections held on April 6th, which returned Fascisti representatives to the Italian parliament in an overwhelming majority.

E. H. Foster.

NEW YORK OFFICE NEWS

We have just received the important notice that Mr. Louis Lauyi, manager of our Detroit office, has become the father of a baby boy. We congratulate you, Louis.

To our Readers:—

This is merely a parting word. In the past year and a half the Foster News has grown from an idea to a paper that has proved itself well worthwhile. The writer wishes to take this opportunity to thank all our readers for their hearty cooperation in helping to make this paper what it is, and also to ask that you give the incoming editor, Mr. L. R. Dulon, of the New York office, your fullest support.

Yours very truly,

G. G. Van Tuyle.

At the Hell Gate Station of the United Electric Light and Power Company, cut of which appears on the cover page, we have equipped 3-1550 H. P. Springfield Boilers with Foster Superheaters and Economizers.

OUR PERSONNEL AND THEIR ACTIVITIES

JOSEPH J. NELIS

Joseph J. Nelis was born in Brooklyn, New York, December 10, 1876.

Early education consisted of Public Schools, night school and two I. C. S. courses at sea.

Later education and experience consisted of six years on ship repair and as apprentice machinist with Erie Basin Iron Works, six years at sea as oiler and engineer, part of this time in the U. S. Navy during the Spanish-American War, sixteen years with The Stirling and Babcock Companies as Marine Erector, Service Engineer and Salesman, and one year with The U. S. Shipping Board in Boiler Department.

Since July 1919 Mr. Nelis has been with the Power Specialty Company in the Marine Department and he hopes to remain with the Power Specialty Company until, as expressed in his own words, he can retire on a farm which is the ultimate aim in life of all seafaring men.

MARINE MUSINGS

The former German raider, the "S. S. Prinz Eitel Friedrich" which terrorized Allied shipping before the United States entered the war, was taken over by the Navy, re-named "Otsego" and operated as a transport until the latter part of 1919. It was then turned over to the Shipping Board and was placed in the laid-up fleet until January 1924 when Libby, McNeil and Libby bought it for conversion into a salmon cannery tender for Alaskan Waters. The ship was formerly equipped with Scotch boilers, but the Shipping Board later replaced these with three Foster 3050 sq. ft. marine boilers.

The S. S. West Calumb returned to this port during the month of May after a six months voyage to the Far East. Twenty-seven ports throughout the Dutch East Indies were visited, all on scheduled time, a total of 26,000 miles being covered during this voyage. The return cargo of 9,000 tons consisted of spices, rubber, teak and other products of the Far East.

The West Calumb, like her sister ships, is equipped for carrying crude rubber in liquid form in her double bottoms. This is pumped into the ship in Ceylon, or Singapore and then pumped from the ship into tank cars in New York to be shipped by rail to the various works in the Middle West.

This is a Shipping Board ship operated by the Kerr Line and is one of the most economical and efficient ships under the American flag. Not one penny had to be spent for repairs on the boilers after this trip which is a record for the mileage. Between Port Said and Boston, a distance of 5,500 miles, not a stop was made during the 21-day trip.

The Chief Engineer, J. B. Hodges, has just been listed by the Fuel Conservation Committee of the Shipping Board as having qualified for the bonus offered for engineering efficiency. He has also earned the reputation amongst the marine representatives of having the cleanest ship that has ever entered this port.

The West Calumb was built by the Los Angeles Shipbuilding & Dry Dock Company in 1919 and is equipped with 3- 4150 sq. ft. Foster marine boilers and 3- 3500 I. H. P. triple expansion engines.

PIPE STILLS

The convenient type of tank or cylindrical still has been in universal use for so long it has become more or less of a standard, but the superior merit of a tubular heater with a vapor separating tower, as a distilling unit, is now very generally recognized. Tubular heaters or pipe stills have long been used for topping operations and until recently their capabilities were supposed to be confined to taking off a preliminary cut. Tubular heaters are now being used most successfully for a variety of refining processes and are becoming of increasing importance because of lower refining cost and better quality of product.

Recent developments in cracking oil at high temperatures and pressure have emphasized the desirability of tubular heaters, commonly referred to as pipe stills, for heating oil. Large quantities of oil contained in cylindrical stills of large diameter, set directly over the furnace with the bottom sheets completely exposed to the fire, are a constant menace because small leaks will rapidly develop into fires of proportions large enough to involve considerable monetary loss. Such fires are often destructive of life as well as property. The quantity of oil contained in a tubular still is only a fraction of the contents of a cylindrical or tank still. In addition to this, the oil is split up into a number of small streams contained in tubes of small diameter, comparatively few of which are exposed directly to furnace heat. In this way the fire hazard is greatly reduced, because a pipe still can be quickly drained of oil should a leak develop, and the damage is confined to the tube in which the leak occurs. Tube replacements can be made without disturbing other tubes or cooling off the heater. Repairs of this kind can be made in a pipe still at much less cost, and the equipment is out of commission for a much shorter time than required to repair a tank still.

In addition to the safety feature, oil is more uniformly heated in tubular construction than is possible when oil in large volume is heated in a cylindrical tank directly over a furnace. All sorts of devices such as bottom steam, have been used to prevent overheating of the bottom sheet and burning of oil in contact with it, but none of these is as effective as circulating oil through a comparatively small pipe or tube at a high rate of speed. The oil is thoroughly broken up and mixed in the tube and any particle is only momentarily in connection with heating surface. The outside of the tubes is surrounded by hot furnace gas, or partially exposed to radiant heat from the furnace. In fact, heat is supplied by heated gases which may be considered as being distributed all through the mass of oil being heated, the oil being contained in tubes around which the heating medium circulates. In this way heat is brought in much more intimate contact with oil than when heat is absorbed through the bottom sheets of a cylindrical still.

A certain prejudice for the tank still has led to the belief, not uncommon, that oil can be heated in a cylindrical still with less danger of burning or overheating than in a tubular heater. It is only necessary to consider the mechanics involved to realize that this cannot be so. The requirement is to heat a quantity of oil to a desired temperature without overheating any part of it. Can the heat be more uniformly applied by confining the oil in large volume and applying intense heat to less than half of the circumference of the containing vessel, or by passing the oil through a number of very much smaller containers, heat being applied for the entire circumference of each of the small containers? The answer is obvious.

This is why tubular heaters are now being used successfully for re-running light distillates, replacing steam stills, and are heating Pennsylvania crude to 650° without burning. The cylinder stock produced is a more desirable product and is made with less than one-third the steam formerly used to produce steam refined stock. Tubular heaters are also in successful use for many other distilling operations, but these two are mentioned as fair examples where heat must be properly applied to produce satisfactory results. It was a long time before the average Pennsylvania refiner could be induced to depart from old, but tried, methods and even consider tubular construction. But the tubular installations already made are giving such successful results that tubular construction is now of much interest.

Fuel consumption in refineries, as elsewhere, is becoming increasingly important. With the old type of still, flue gases left at a high temperature and only a small percentage of heat in the fuel was used in heating oil, the larger part being wasted up the chimney. Sometimes the heat used amounted to not more than 30% of the heat in the fuel. With tubular construction the heating surface is so flexible that it can be arranged so that oil flows through the heater in a direction opposite to the direction of flow of the hot furnace gases among the tubes. The flue gas just before leaving the heater is thus brought in contact with the coldest oil entering the heater and the temperature of the flue gas reduced to within 100° to 200° of the temperature of the entering oil. In this way comparatively little heat is wasted up the chimney and with proper furnace construction, 75% of the heat in the fuel can actually be used in heating oil. There are tubular heaters in operation, day in and day out, where the fuel efficiency is even better. Tubular construction evidently possesses very distinct advantages from the viewpoint of better products at lower cost of fuel, and so should not be overlooked by the progressive refiner.

In order to provide proper rate of flow through tubular heaters, a pump is necessary. Mechanical difficulties with the pump and the power required to drive it have been advanced as reasons why tubular heaters should not be used. Mechanical difficulties existed only where it was necessary to pump hot oil, and due to the efforts of many of the pump manufacturers these difficulties have gradually been overcome until to-day it is quite possible to obtain pumps of a number of different makes which have demonstrated their ability to successfully pump oil at temperatures of 750° or 800°. Where steam-driven pumps are used the exhaust steam can be dried, possibly superheated, and is usually sufficient in quantity, when exhausted into a vapor separating chamber, to lower the boiling point to the desired temperature by reducing the vapor tension. When the exhaust steam is used in this way, the pump actually becomes a reducing valve and the steam passing through the pump should not be charged against

FOSTER NEWS

"Better Thru Understanding"

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1776-1924

ONE hundred and forty-eight years have passed since the founding of our United States of America. Let all of us of The Power Specialty Company do all in our power now and in the future to make this great country of ours the finest place in the world in which to live.

The American Flag

When Freedom from her mountain height
Unfurled her standard to the air,
She tore the azure robe of night,
And set the stars of glory there.
She mingled with its gorgeous dyes
The milky baldric of the skies,
And striped its pure celestial white
With streakings of the morning light;
Then from his mansion in the sun
She called her eagle bearer down,
And gave into his mighty hand
The symbol of her chosen land.

Majestic monarch of the cloud,
Who rear'st aloft thy regal form,
To hear the tempest trumpings loud
And see the lightning lances driven,
When strive the warriors of the storm,
And rolls the thunder-drum of heaven,
Child of the sun! to thee 'tis given
To guard the banner of the free,
To hover in the sulphur smoke,
To ward away the battle stroke,
And bid its blendings shine afar,
Like rainbows on the cloud of war,
The harbingers of victory!

Flag of the brave! thy folds shall fly,
The sign of hope and triumph high,
When speaks the signal trumpet tone,
And the long line comes gleaming on.
Ere yet the lifeblood, warm and wet,
Has dimmed the glistening bayonet,
Each soldier eye shall brightly turn
To where thy sky-born glories burn,
And, as his springing steps advance,
Catch war and vengeance from the glance.

And when the cannon-mouthings loud
Heave in wild wreaths the battle shroud,
And gory sabres rise and fall
Like shoots of flame on midnight's pall,
Then shall thy meteor glances glow,
And cowering foes shall shrink beneath
Each gallant arm that strikes below
That lovely messenger of death.

Flag of the seas! on ocean wave
Thy stars shall glitter o'er the brave;
When death, careering on the gale,
Sweeps darkly 'round the bellied sail,
And frighted waves rush wildly back
Before the broadside's reeling rack,
Each dying wanderer of the sea
Shall look at once to heaven and thee,
And smile to see thy splendors fly
In triumph o'er his closing eye.

Flag of the free heart's hope and home!
By angel hands to valor given;
Thy stars have lit the welkin dome,
And all thy hues were born in heaven.
Forever float that standard sheet!
Where breathes the foe but falls before us,
With Freedom's soil beneath our feet,
And Freedom's banner streaming o'er us?

Joseph Rodman Drake.

---

the heater. The steam required for vapor tension is but a small fraction of that usually used for bottom steam to agitate the oil and cool the bottom sheets. Consequently there is a large amount of steam saved by distilling in a tubular unit. This should not be overlooked when considering first cost and operating expense.

The foregoing remarks apply only to tubular heaters in which the design has been given careful consideration and is the result of experience. It is not intended to convey the impression that any convenient arrangement of tubes over a fire will produce the results noted, because such is not the case. There are many features such as oil velocity, rate of flow of furnace gases over the tubes, disposition of heating surface with relation to the fire, etc., which must be considered in individual cases, to produce the results required. Fortunately such knowledge and experience is now available.

John Primrose.

SEAMLESS TUBES

The steel from which seamless steel tubes are made must be of the very highest quality. The piercing process "uncovers" rather than "covers up" steel defects, making their detection and rejection in inspection an easy matter. The users of seamless tubes are thereby assured a product practically free from seams, laminations and other injurious defects. The blooms, from which rounds for the manufacture of seamless tubes are rolled, are carefully inspected and chipped and then charged into a continuous heating furnace. The blooms are laid on water-cooled skid pipes and shoved through the furnace by means of a hydraulic ram. The blooms are thus gradually worked through the furnace and brought up to a rolling temperature.

Before withdrawing from the furnace the bloom is turned over on the hearth and allowed to remain there a sufficient length of time to insure uniform and thorough heating.

The overhead charging crane removes the heated bloom from the furnace and delivers it to the traveling tilting table.

The electrically driven bar mill consists of four stands of rolls, 24" diameter, three high, and is served by two traveling tilting tables, one on either side.

All roughing is done in diamond passes, as this shape pass is recognized as giving better rolling conditions than any other.

The bloom is gradually rolled down and finished into a round, the size of which depends on the size of the tube into which it is to be made.

The increasing length of the bloom as it is rolled down is handled on run out tables, which serve as extensions to the traveling tilting tables.

From the finishing pass the bar runs out on driven tables to the hot saw, where it is cut into short lengths.

The long bar runs up to the saw where the crop end or fish tail is trimmed off, and the bar is then fed up to a stop, set at the proper length to give the required weight. As soon as the bar is against the stop the saw is advanced through it. The actual time required to cut through the bar is from three to five seconds, depending on the diameter of the bar.

The tube billets, as they are now called, are piled from the hot saw, two high, on skids and while still hot are immersed in the pickling vat. This method of pickling the steel hot has the distinct advantage that when removed from the vat the surface of the steel is a light gray, on which every defect is plainly visible.

After pickling, every round is carefully inspected and chipped. The practice of pickling and chipping tube rounds is an exclusive feature of the manufacture of Seamless Tubes, and is only one evidence of the extreme care used to insure a high quality of product.

After chipping, the billets are delivered to the tube mill yard.

Into one end of each billet a hole about one inch in diameter and one inch deep is drilled. This is to facilitate entering the billet in the piercing mill.

The centered billets are then charged into a continuous furnace with a sloping bottom. As the heated billets are removed from the lower end of the furnace those behind keep rolling down.

The heated billet is fed into the piercing mill by means of an air ram.

The piercing mill is of the overlapping disc type, known as the "Stiefel" mill. The billet, entering between the discs below their centre line, has imparted to it a motion of rotation and translation.

A horizontal cross section through the discs would show a converging and diverging pass with a conical shaped plug resting on a lower guide shoe and the end of the plug extending a short distance beyond the narrowest part of the pass. It would also be seen that the angle of the plug is the same as the outlet angle of the discs. The plug is held in position by means of a long bar carried in a thrust bearing, this in turn is held by latch keys which can be withdrawn to permit removal of the bar.

A guide shoe is also placed over the plug.

The heated billet on being fed to the discs is gripped by them, and reduced in diameter as it is pulled to the center of the pass. This reduction in diameter serves as "draft" to force the billet over the plug. As the billet passes the centre line it increases in diameter, being forced over the plug. The wall thickness of the pierced billet is determined by the distance between the parallel surfaces of the plug and discs.

When the billet has passed entirely over the plug the bar is removed and the pierced billet rolls to the 2-high rolling mill receiving table.

During the piercing operation the plug becomes heated and must be cooled before being used again. In practice several plugs are kept in a bosh of cold water and as soon as a billet is pierced the hot plug is put in the bosh and a cold one placed on the bar.

The actual time required to pierce a billet varies with the length, but on an average is about ten seconds and the complete cycle is frequently made in fifteen seconds or less.

The pierced billet which has heavy walls and is rough and uneven on the surface goes without reheating to the receiving table of the 2-high automatic return rolling mill. The function of this mill is to reduce the wall of the billet and bring it approximately to gauge. A plug is held in the pass line between the rolls by means of a long, hollow, water cooled bar. The bar is held by means of a heavy yoke which is tied to the roll housings with large rods. The billet is pushed into the rolls by means of an air ram, is gripped by the rolls and pulled over the plug, thereby reducing its wall thickness.

As soon as the billet has passed entirely over the plug an air operated wedge, which is placed between the upper roll and the adjusting screws, is removed. The upper roll is automatically raised by the powerful springs located on top of the housings so that sufficient clearance is provided for the return of the rolled tube. The return of the tube is accomplished by means of a pair of rolls running in the opposite direction to the main rolls. The "stripper" rolls, as they are known, are brought in contact with the tube by means of air cylinders.

Two passes of a billet through the rolling mill are usually sufficient to bring it to the proper wall thickness. The production of the rolling mill keeps in step with that of the piercing mill.

The rolled tube is then delivered without reheating to the reeling machines. Two of these machines

are required to keep up with the production of a single rolling mill.

The function of the reeling machine is to true up the diameter and smooth and polish the inner and outer surfaces, and also reduce the wall thickness of the rolled tube.

The reeling machine consists of two driven rolls with their axes at an angle to each other, the distance between the rolls being adjustable by means of a hand wheel. A cylindrical plug, held in position in the same manner as the piercing point, rests between the rolls on a guide shoe.

The rolled tube is fed to the reeling machine on a driven conveyor, is gripped by the rolls, and while being rotated, forced over the plug. Heavy pressure is exerted on the walls of the tube while passing over the plug and this serves to accomplish the functions of the machine.

From the reeling machines the tube goes either to the sizing mill or the reducing mill. In the case of "Hot Finished" tubes or tubes three inches and over in diameter, they go through the sizing mill. This mill consists of three pairs of rolls and serves to bring the tube to the exact diameter required.

When a tube of less than three-inch diameter for cold drawing purposes is desired, the rolled tube is delivered to a reheating furnace. From the furnace the tube passes through the reducing mill. This mill consists of thirteen pairs of rolls and the tube passing through this series of rolls can be reduced in diameter very appreciably.

The tubes from the sizing and reducing mills are delivered to a cooling table where they are carried up an incline by means of paddle conveyors. The tubes keep rolling as they pass up the cooling bed and are thus uniformly cooled.

Seamless tube products may be divided into two general classes, hot finished and cold drawn.

The process of manufacture for the two different classes is identical through the bar mill, piercing and rolling mills, and reeling machines. As mentioned previously the hot finished tubes are sized hot while tubes which are to be finished by cold drawing are not.

The rolled tubes are carefully inspected for steel and mechanical defects and then sent to the Cold Drawing Department. The first operation in this department is that of pointing. One end of each tube is heated for a distance of about eight inches and then hammered down by means of an air steam hammer. It is necessary to point the tubes in order to provide a section of smaller diameter than the tube so that it can be inserted through the die and be gripped by tongs.

From the pointing hammers the tubes are transferred to the pickling department. Here they are first immersed in a hot dilute solution of sulphuric acid which removes all rolling scale. After pickling, the tubes are rinsed in clear water and then dipped in a lubricant composed of flour, tallow, and water. After the lubricant has been allowed to dry on the tubes for about twenty-four hours they are delivered to the benches for cold drawing.

The draw bench is constructed of long heavy cast iron channels, with a heavy cast iron head located about the centre of the channels for supporting the cold draw die. At the rear end of the bench is located a stop which holds the mandrel rod in position. A heavy chain travels from the die head to the front of the bench. Into this chain the buggy, which carries the grips, is hooked.

In cold drawing a tube, a die and mandrel, of proper size to make the desired tube, are selected. The die is placed in the die head and the mandrel screwed on to the mandrel rod and adjusted to the proper position in relation to the die. The mandrel is then pushed into the tube and the point of the tube inserted through the die. The point is caught in the grips carried in the buggy and the buggy hooked into the chain. As the chain carries the buggy forward the tube is drawn through the die and over the mandrel, reducing both the diameter and wall thickness at the same time.

Cold drawing leaves the material in the tube in a hard, brittle condition, unsuitable for any purpose which requires ductility of material. To restore the ductility the tubes are annealed. The degree of anneal depends on the purpose for which the tubes are to be used. The annealing furnaces used are fired with producer gas, the tubes being shoved on to the hearth and withdrawn by hand.

Many sizes and classes of tubes require more than one cold drawn operation to finish. In such cases the tubes are annealed, pickled and lubricated after each pass. After the tube has been cold drawn to the finished size and given the proper anneal, it is delivered to the Finishing Department.

We will first follow the hot finished tubes through the finishing operation.

The final operation of this class of tubes in the hot mill is that of sizing. From the sizing mill the tubes are delivered to the cooling table. Traveling up the cooling table the tubes rotate and are thus uniformly cooled.

At the end of the cooling table the tubes drop on on to a driven conveyor which feeds them into a rotary straightener. This type of straightener is the latest development in tube straightening machinery and delivers the tubes almost perfectly straight.

From the straightening machines, the tubes go to the cut-off machines where the ends are trimmed and the tubes cut to length.

From the cut-off machines the tubes roll to the inspection tables. Here they are given a very rigid inspection for both mechanical and steel defects. Inspection of the interior surface is made by use of a light held at one end of the tube while the inspector looks through from the other. A trained inspector becomes very proficient in finding defects which are not discernible to one not so trained.

At the cut-off machines are also cut the short pieces on which expanding, flattening and crushing tests are made.

All tubes which have passed inspection are then sent to the hydraulic testing benches where they are given a hydrostatic test of 1000 pounds per square inch. After passing the hydrostatic test the tubes are stenciled and loaded for shipment.

Cold drawn tubes after final annealing are delivered to the Finishing Department where the first operation is that of straightening.

Three different types of machines are used in straightening cold drawn material. The "twelve roll" straightener, press straightener, and rotary straightener.

After straightening the tubes are cut and inspected the same as hot finished tubes.

Cold drawn mechanical tubing does not require a hydrostatic test, and after inspection is ready for stenciling and shipment. Cold drawn boiler tubes after inspection are given a hydrostatic test and then stenciled and shipped.

SOME USES OF SUPERHEATED STEAM IN MANUFACTURING PROCESSES

We generally think of superheated steam as it relates to the power plant, but there have been many other uses found for it where it is most desirable and makes it possible to save time and money in a number of manufacturing processes. It will doubtless be of interest to cite some of these particular uses which have proved satisfactory.

A special article was published some time ago in The News, relating to the use of superheated steam in digestor work in a paper mill. This is typical of manufacturing processes where steam is used as a heat conveyor to the process. Superheated steam is of special value in a case like this because the steam is condensed in the process and the water of condensation reduces the effectiveness of the acid solution. By furnishing the needed heat with less pounds of steam, there is less dilution, thus resulting in a stronger solution in the digestor, or viewed from another standpoint, the same strength with less chemicals to start with.

A somewhat similar use of superheat is that for deodorizing vegetable oils, where the steam is blown through the oil to raise its temperature and drive off fatty acids. This method was found most successful in this process where close regulation of the temperature of the oil was desirable and where overheating would be a detriment, and the desired results were obtained with great success and many installations of this kind have been made. However, recently this use of superheated steam has largely disappeared, for the reason that we have proved that by a continuous circulation of the oil through one of our oil heaters the same results can be obtained at very much less fuel expense.

Superheated steam has been successfully used in various other processes where the steam is admitted directly to the mass of material to be heated. Its advantage in a process of this kind comes from the better permeation of the steam into the mass, thus bringing up the temperature faster and with less dilution in the mass, due to the condensation of the steam. An example of this kind is the use of superheated steam in soap vats.

Scarcely a week goes by without our receiving an inquiry from some company desiring to use superheated steam to get a temperature effect in some indirect heating process, where the steam is introduced into a coil. Superheated steam can be and has been used successfully for this purpose but there is a great deal of misapprehension about its use in this manner. The fact that superheated steam has a high temperature regardless of pressure attracts the attention of a great many engineers, who jump to the conclusion that all they have to do is to introduce the superheated steam into the coil and a high temperature effect will result. Most of them entirely overlook the fact that the total heat in the superheated steam is small as compared with the latent heat in the saturated steam and that this heat, due to superheat, is not available unless all the steam in the coil is maintained at a temperature above that desired in the process. By rapidly circulating steam through the coil so that it escapes at a temperature higher than that required, it is possible to utilize this heat in this manner, provided also that we bear in mind that the conductivity of superheated steam is poor as compared with saturated steam and that this factor must be considered in designing the heating surface.

Unless a secondary use is found for the steam escaping from this coil, this would be a most uneconomical method to use, hence it is only possible where the latent heat can be utilized in another process or for power purposes.

In some plants special means for getting this circulation are possible, as, for instance: in a soap works some years ago they ran one boiler at a higher pressure than the rest, superheated the steam in the high pressure boiler and circulated through the coils in their glycerine still back to the boilers at the lower pressure, where steam mixed with the other steam and went out to the plant for general use.

A very interesting use for superheated steam has been found in the water gas process, where steam is blown through the incandescent mass of fuel in the generator. This steam is naturally at a very much lower temperature than that of the fuel bed and has a cooling effect. By using superheated steam there is less cooling effect and, therefore, the length of time of the run can be increased, or the quantity of steam blown during a run of the same time increased, thus producing more gas per run.

A similar use of superheated steam has been made in gas producers. In this process steam is usually introduced to keep down the temperature of the fuel bed; consequently if it is superheated, a larger amount may be used without reducing the temperature too much. The more steam used the larger the percentage of hydrogen in the producer gas. This may or may not be desirable, depending upon the purpose for which the gas is used. Therefore, in work of this kind the value of superheated steam depends to a considerable extent upon the type of producer and the kind of gas that is to be made.

Superheated steam is very largely used in oil refineries in shell stills, where it performs a double duty—first, it is delivered from perforated pipes close to the shell bottoms, in order to provide a circulation to prevent overheating of the shells, and second, its presence in the oil reduces vapor tension and aids in carrying off the oil vapor. This use of superheated steam is particularly desirable in refining of oils that contain lubricating stock.

For this last named purpose we have supplied a large number of direct fired and waste heat type superheaters for superheating low pressure steam, as pressure is not required, and this use of superheated steam offers a considerable field for our equipment.

Another use for superheated steam that has proved most satisfactory is in the railroad roundhouse for blowing engines. This use of steam consists in obtaining a draft by the use of steam jets in the smoke pipe and the value of superheated steam comes from the fact that the increased volume due to the superheat is taken advantage of to produce the desired draft with a less weight of steam. While this use of superheated steam has not come into

UTILIZING RADIANT HEAT

In designing a boiler furnace one of the first essentials is to consider the way in which the heat generated in the furnace is to be utilized. Modern practice in the power industry is tending toward higher steam pressures and temperatures. To put in practice what theoretical calculations have shown to be most economical, many changes in the design of furnaces have been necessary.

To burn the fuel completely is the duty of the furnace; to utilize that heat in the generation of steam is the function of the boiler. The more of the heat that can be used in this way, the higher will be the efficiency. It is, therefore, essential to distribute the heat absorbing surfaces so as to make best use of the heat generated.

In the transfer of heat from one gas or liquid to another, the counterflow principle has given the highest efficiency. In the generaton of steam this principle has been applicable only to a limited extent. Several types of water-tube boilers used in connection with economizers come the nearest to the counterflow principle that has been developed; the temperature difference between the water in the tubes and the gases in the furnace, however, is excessive, amounting in many cases to 2000 deg. F.

One of the big problems in furnace design has been to proportion the walls and arrange the heating surfaces so as to maintain a temperature which will insure complete combustion yet will not melt down the furnace lining or cause clinkers. When anthracite and low volatile eastern coals were the common fuels in power plants, combustion space requirements were moderate and the boiler was placed down near the fuel bed or, as in the case of internally fired boilers, the heating surface completely surrounded the burning fuel. This kept the furnace temperature low but such an arrangement also kept down the possible rate of combustion so that with high volatile coals combustion of the gases is incomplete.

Bottling the heat by means of dutch ovens, arches, roof tiling and wing walls has been resorted to for securing complete combustion but, at the high combustion rates now in general use, this results in melting down the furnace linings and causes clinkers.

Where high rates of combuston are employed, the tendency now is to build large furnaces and keep the temperature down by exposing more heating surface to the radiant heat of the furnace. This may be accomplished by rearranging the boiler baffing, providing water backs for the front of the bridge wall, supplying water screens to prevent fusion of ash in powdered fuel furnaces and the most recent arrangement is by lining one or more of the furnace walls with steam superheating surface. This last arrangement extends the use of the counterflow principle of heat exchange in boiler and has worked out very satisfactorily in a number of plants. Steam temperatures as high as are likely to be employed for power purposes can be maintained and space occupied is that which would otherwise be required for furnace lining.

Power Plant Engineering, May 15, 1924.

DANSVILLE NEWS

We understand that our Superintendent, Mr. Reigart, has so designed the front porch of his Conesus Lake Cottage, that he can sit in a Morris chair and fish.

With "No Auto Parking between the white posts" each side of the gate house and main office, has avoided many of those narrow escapes of passing tourists.

At a meeting of the baseball organization held May 13th, Clarence Burly was made Captain and H. M. Pickard was elected Manager. We have the making of a good team and the promise of many games with teams of surrounding towns. Get behind the team and boost!

---

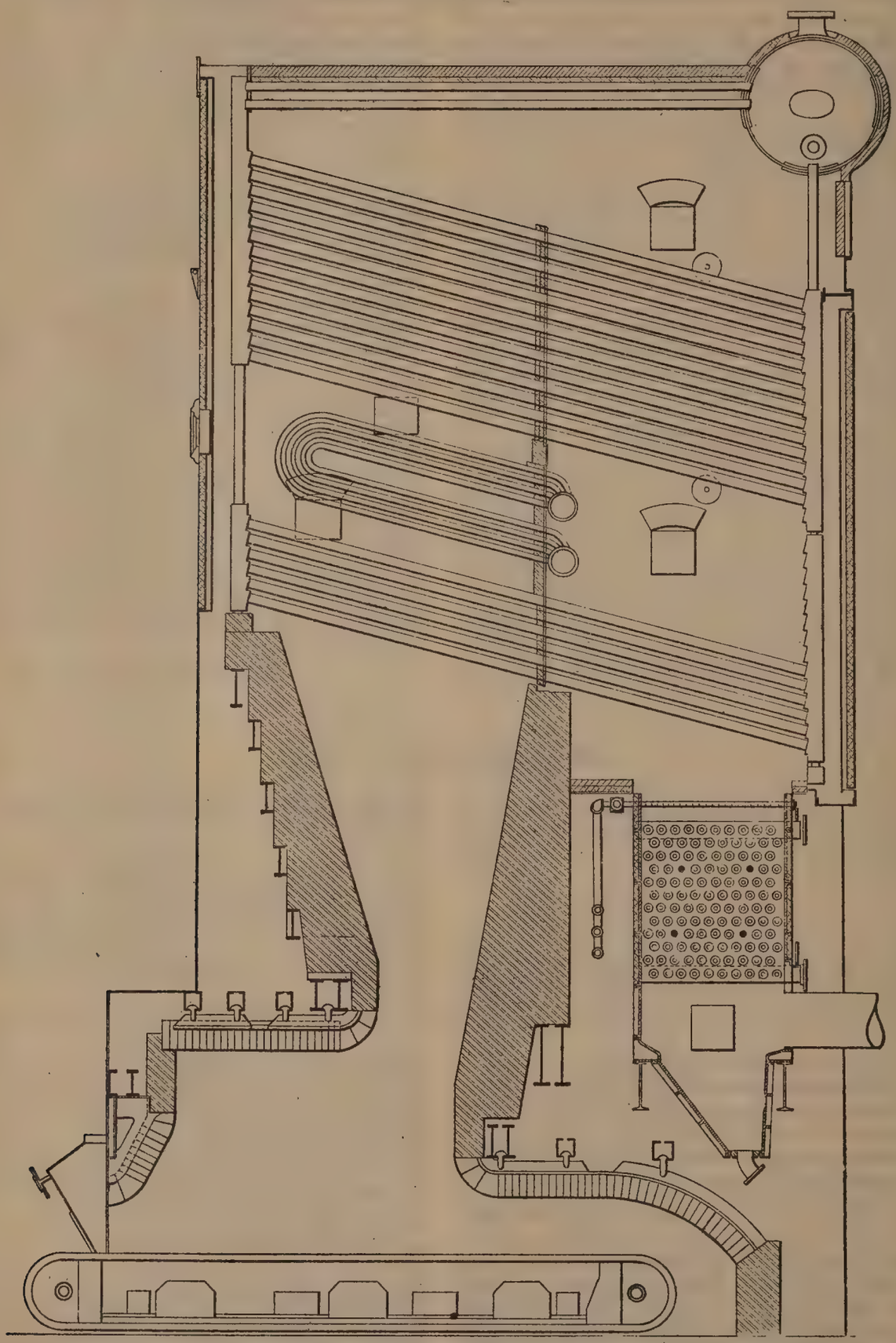
general practice, it offers an excellent field and a great many railroad engineers are beginning to appreciate its value. Our equipment has already been installed in a good many roundhouse plants.

A very interesting article recently appeared in The News regarding the use of superheated steam for laundry work. Apparently superheated steam is proving most satisfactory in these plants. Its success is a little bit difficult to understand as the steam is introduced into steam chests and drum dryers, but the writer believes that the success of these installations probably comes from the delivery of the steam into the chest at a higher pressure. Saturated steam probably reaches this equipment with a considerable moisture content and the admission of this wet saturated steam through the relatively small ports decreases its pressure materially. By delivering the steam dry, it arrives at the point of use at a pressure much nearer that of the boiler, and therefore, containing more heat at a higher temperature available for the work. It would be very interesting for our Engineering Department to develop whether this is the real reason for the success of this type of installation.

There are many other minor uses for superheated steam that have found limited use. In textile mills we have supplied equipment for color fixing; in chemical plants for use in autoclaves and in a number of other industrial processes. No doubt still further uses will develop in the future and will offer still wider fields for our equipment.

Robert H. Wyld.

Heating Surface Babcock & Wilcox Boiler	*19,831 sq. ft.*
Heating Surface Foster Economizer	*6,264 sq. ft.*
Steam pressure	*275 lbs. per sq. in.*
Ratio of Economizer heating surface to Boiler heating surface	*31.5%*



Foster Economizers as applied to two pass Babcock & Wilcox boilers at the South Amsterdam Plant of the Adirondack Power and Light Corporation, Schenectady, N. Y. These economizers are the one pass type with gases passing downward and water forced upward and are located below the boilers at the last pass requiring a minimum space.

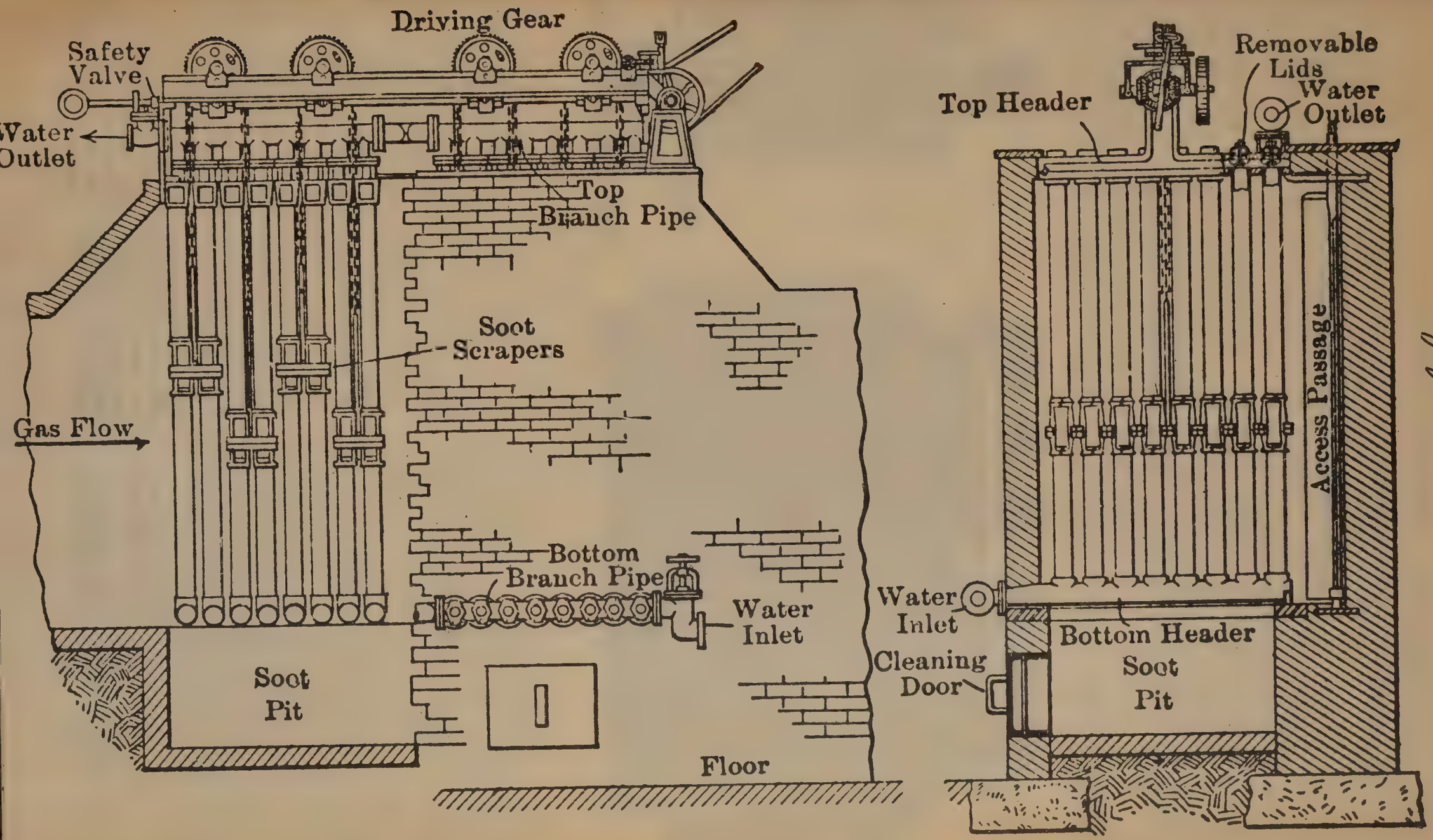


Fig. 427. — Economizer.

Plaintiff's Exhibit 11.

Plaintiff's Exhibit 12. 11-16-27

into the soot pit, as the side wall is outside of the bottom header. No brick work need be removed, and, therefore, it is not necessary that a mason assist in the repairs of the Sturtevant type. The new bottom header may easily be put in position, and after shoring up both top and bottom headers the pipe may be driven in place.

THE GREEN FUEL ECONOMIZER

The Green Fuel Economizer Co., Matteawan, N. Y.

This consists of a series of vertical cast-iron pipes 4⅝ in. external diameter and 9 ft. in length, which are made up in sections of various numbers of pipes to fill out any desired width. Any number of sections can be assembled to make the economizer of any desired length.

The tubes are pressed into top and bottom headers so that they stand in even rows in both directions. Staggered rows have also been used, but it is found that in a great many plants there is not enough draft to permit of this, while the advantages are largely problematic.

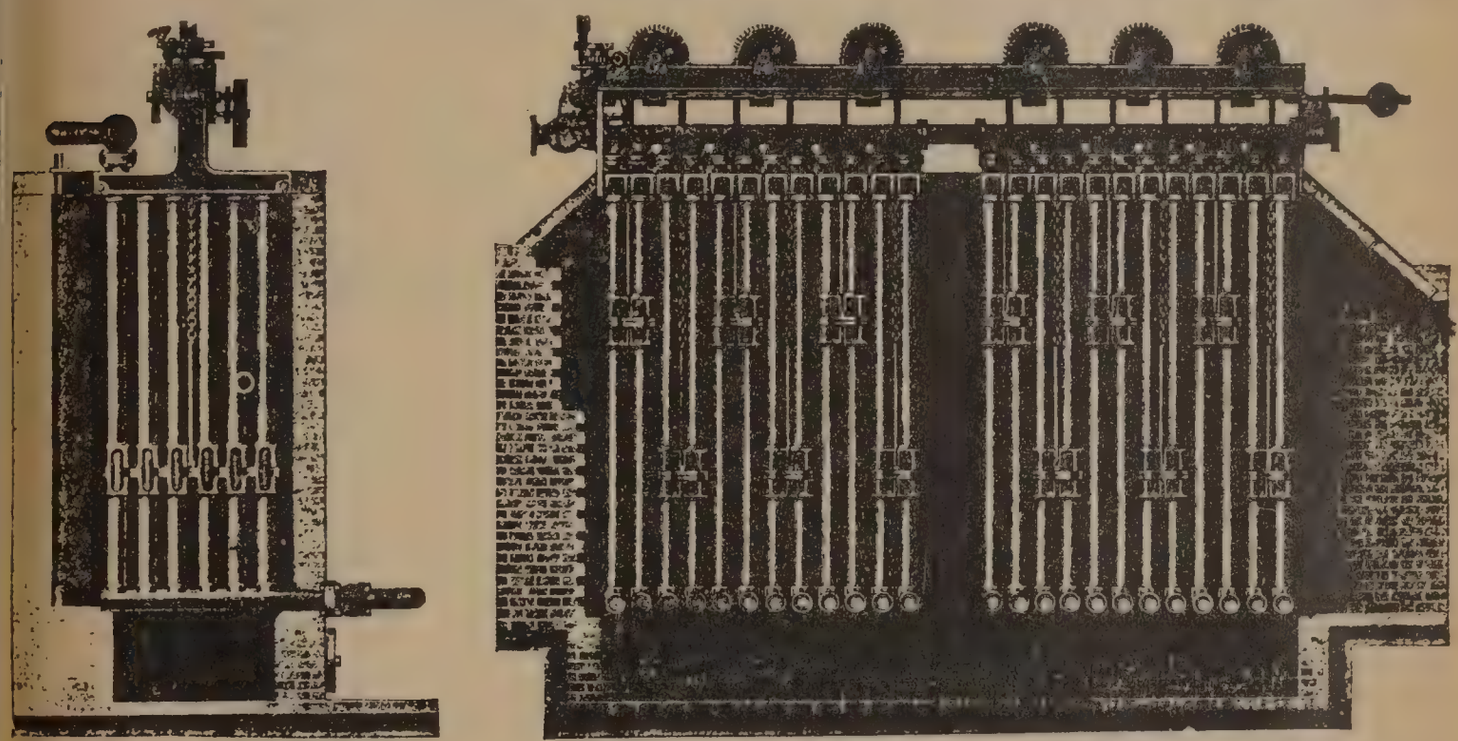
The bottom headers are connected at one side with the branch pipe running along the ends of the bottom headers outside of the economizer chamber. At the diagonally opposite corner the top header connects with another branch pipe, similarly located outside the economizer chamber. Connections to the branch pipes are made by means of gasketed joints, which not only insures tightness, but also gives the slight amount of elasticity required to take care of strains caused by uneven expansion and contraction of the different sections. As the gasket is not subjected to the chimney gases, and is in plain sight, deterioration and leakage are avoided. The hot chimney gases are led to one end of the economizer chamber, pass in among the pipes and escape considerably reduced in temperature and volume at the other end, after circulating among the tubes.

By-passes and dampers are usually provided for laying the economizer off while the boilers are in use. The feed water is usually forced by a boiler feed pump or injector into the economizer through the lower branch pipe, entering at the end of the economizer where the cool gases leave. The water then passes from the bottom headers up through the pipes into the top header and into the upper branch pipe, leaving at the end of the economizer where hot gases enter.

In order to keep the outside of the tubes clean of soot scrapers, driven by an automatic gear placed on top of the economizer outside of the chamber, pass slowly up and down. The soot thus removed from the tubes falls to the bottom and through into the soot chamber; the bottom headers in the Green fuel economizer being of a specially narrow form, which leaves sufficient room for the soot to fall through or even for the entrance of a man's arm for the replacement of scrapers, etc. The soot chamber is sometimes provided with an automatic cleaning arrangement driven from the same source of power as the scrapers.

In order to give access to the inside of the economizer, hand-holes are provided in the bottom access pipes, one opposite each bottom header, also in the top headers, one opposite each pipe. The handhole plates in the top headers are conical, and fit internally so that they are held tight by the pressure of the water. One of the plates of each header is made specially large to permit of the removal of the others. All joints within the economizer chamber are metal-to-metal, no gaskets or packings being used.

The most recent improvement in the economizer is the use of a sectional covering to replace one or both of the brick side walls, this covering being made of a substance which retains the heat better than the brick and does not crack or leak. Furthermore, it can be taken down in sections for cleaning and inspecting the tubes. The covering consists of 2 iron sheets with mineral wool or asbestos between, and with the edges stiffened by angle iron. The economizer is provided with blowout valves, safety valves, means for washing out the tubes and headers, and means for scraping the tubes and cleaning out the soot chamber.

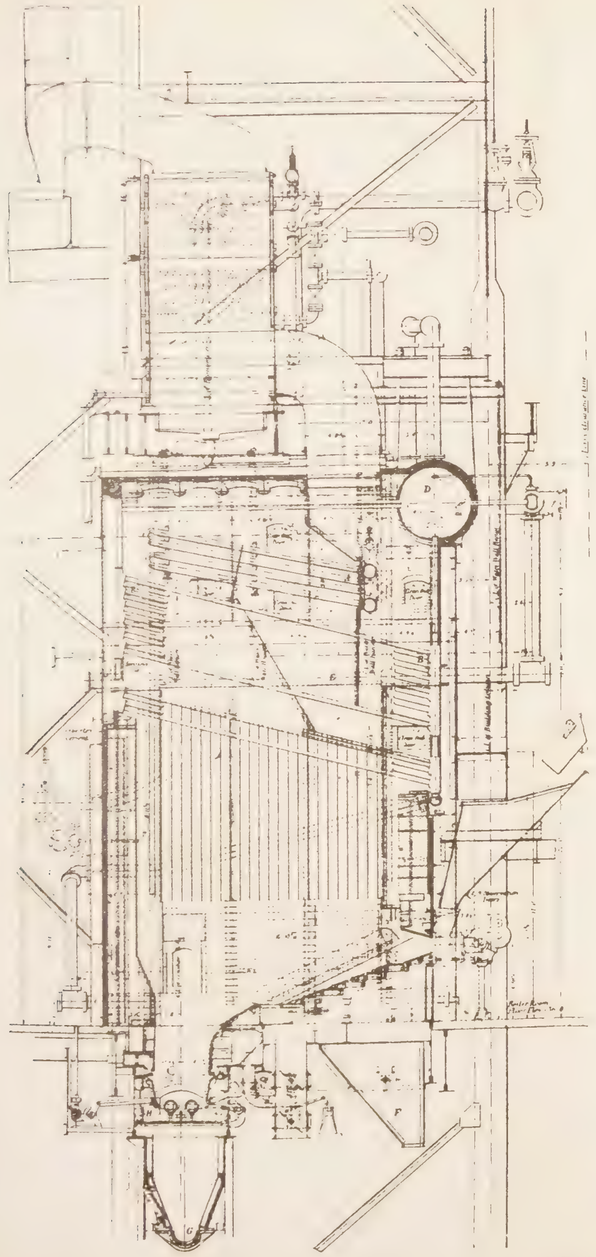


THE GREEN FUEL ECONOMIZER, SIDE AND END VIEWS

One square foot of grate surface will burn 10 to 12 lb. of coal an hour.

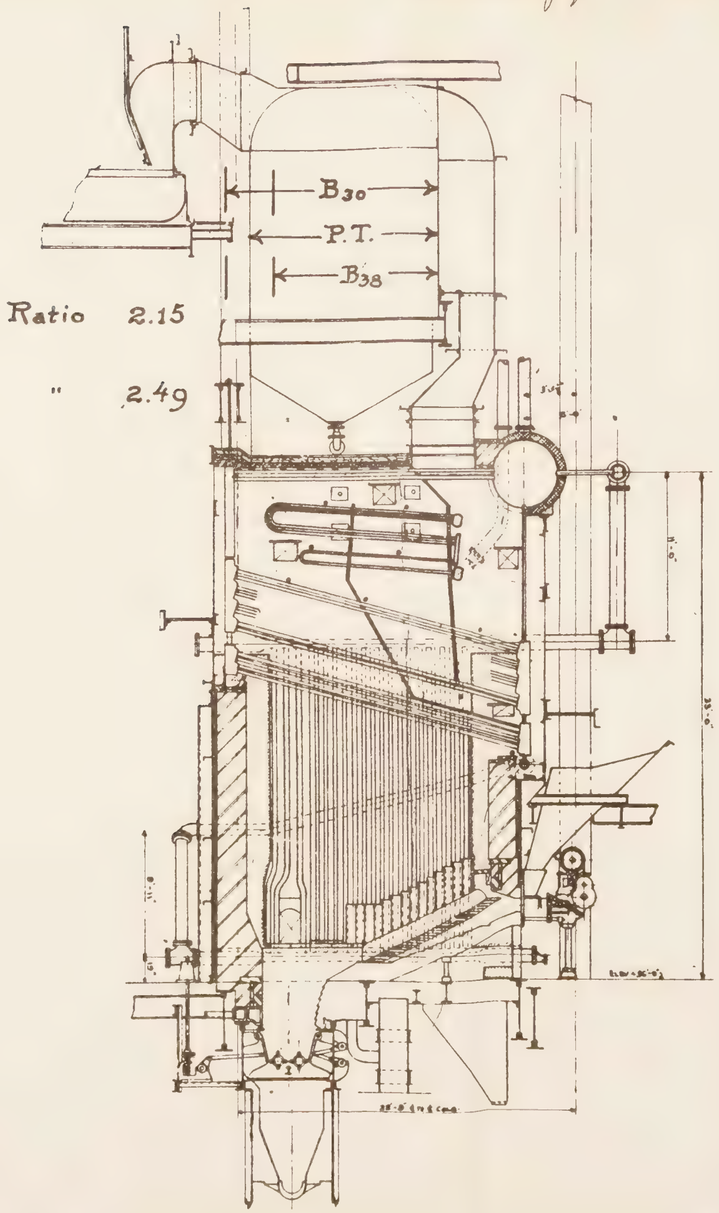
Increasing the lap on a valve lessens the lead, makes admission later and cutoff earlier.

Plaintiff's Exhibit 13.



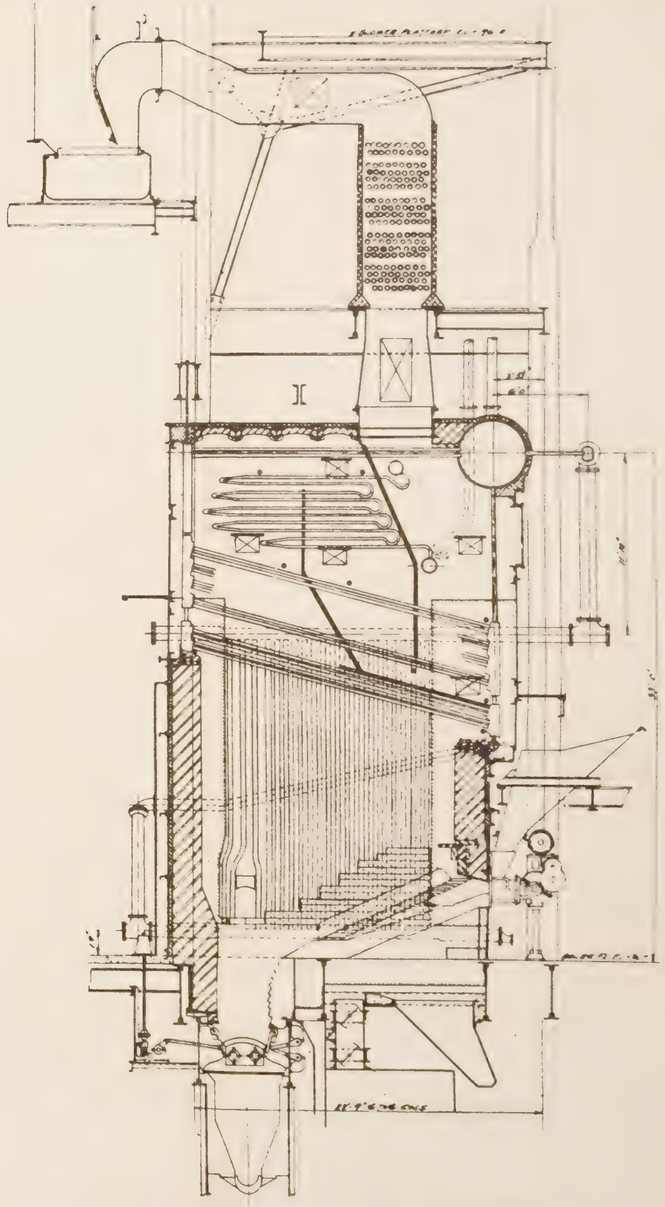
BOILER SETTING—CROSS SECTIONAL ELEVATION—HELL GATE 1923 INSTALLATION

30



BOILER SETTING—CROSS SECTIONAL ELEVATION—HELL GATE STATION BOILERS Nos. 61, 62, 63

36



BOILER SETTING—CROSS SECTIONAL ELEVATION—HELL GATE STATION BOILERS Nos. 71, 72, 73

38

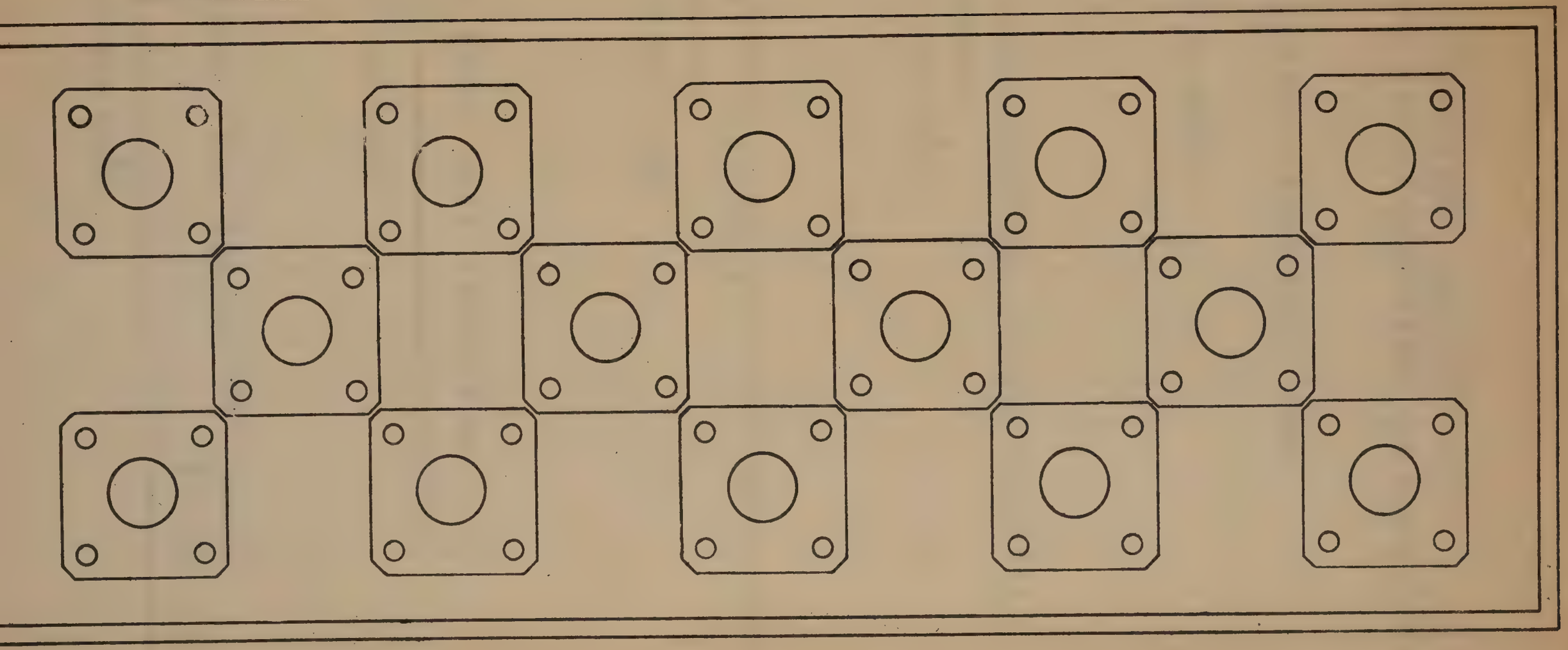
R. KABLITZ

U.S. PATENT Nº 886,516.

FIGURE 5

SHEET 2.

PLAINTIFF'S EXHIBIT. 14.



Plaintiff's Exhibit 15.

COMPARATIVE HEATING-SURFACE per Unit of VOLUME

Green ~~Sturtevant~~ cast iron: Matteawan, 1909

2.60 sq. ft. per cu. ft.

Sturtevant steel plain tube: Middletown, Pa.

4.18 sq. ft. per cu. ft.

Babcock & Wilcox steel plain tube: Weymouth, Boston

4.21 sq. ft. per cu. ft.

Sturtevant gilled tube: Devon, Conn.

10.47 sq. ft. per cu. ft

Bell gilled tube: Power Specialty Co. standard: (9 tubes wide)

13.84 sq. ft. per cu. ft.

PLAINTIFF'S EXHIBIT 16. 871

1922

Serial No. 572,166. Patent No. 1,565,305.

John E. Bell Assor to Power Specialty Company, of New York, N. Y., a corp. of New York.

Steam Generating Plants

Application filed complete July 1, 1922.

Examined and Passed for Issue Oct. 30, 1925.

C. L. Wolcott, Examiner Div. 46

Notice of Allowance Oct. 31, 1925.

Final Fee $20. Nov. 14, 1925.

Patented Dec. 15, 1925. 872

Attorneys—~~Cooper, Kerr & Dunham, 55 Liberty St.~~, New York, N. Y.

Sub. Attorney, John E. Hubbell, 469 Fifth Ave. (Class 122–421)

CONTENTS.

1. *Application papers.*
2. *Sub Power of Atty. Nov. 6, 1922.*
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5. Rejection Apr. 29, 1924.
6. *Power of Attorney Jan. 8, 1925.*
7. *Amendment B Apr. 28, 1925.* 873
8. Rejection Aug. 29, 1925.
9. *Amendment C & Oath Oct. 27, 1925.*
10. Notice of Suit Oct. 22, 1926.

REFERENCES CITED.

772,059, Rice
744,323, Foster
1,281,016, Jacobus
726,243, Beha

Plaintiff's Exhibit 16.

874 1,107,313, Klumph et al
712,490, Blossom et al
1,152,421, Killman
886,516, Kablitz
1,357,493, Foster
1,239,377, Foster
365,801, DeNaeyer
British 2,097 of 1900, Levi
British 24,162 of 1914, Niclausse

Paper No. 1. *Application Papers.*

Petition giving applicant's post office address as 111
875 Broadway, New York, N. Y.

Power of Attorney in the usual form.

Specification—

See printed copy of patent with changes indicated thereon.

Original Claims as follows:

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1. In a steam generating plant comprising a
Ins. A3 boiler furnace and a boiler section A3, the improve-
(p. 8)
ment which consists in an economizer section tra-
versed by the boiler furnace heating gases after
the latter have left the boiler section and through
876 which water is passed into the boiler section, and
Sub C3 formed of staggered rows of steel tubes encased
(patent) in externally corrugated tubular cast iron sections
so spaced and proportioned as to provide an aggre-

–2–

gate economizer heating surface approximately as
great as, or greater than the aggregate boiler heat-
ing surface, and requiring a draft suction at nor-
mal load to move the heating gases through the
economizer section at least as great as the draft

suction required to move the heating gases through 877
the boiler section.

2. An economizer comprising a bank of exter-
per A *horizontal*
nally corrugated tubes spaced so that the average distance between the center of each tube and the centers of the tubes adjacent thereto is in the neighborhood of one and one quarter times the maximum tube diameter.

3. An economizer comprising a bank of exter-
per A *horizontal*
nally corrugated tubes arranged in parallel rows, 878
with the tubes in adjacent rows staggered, and spaced so that the average distance between the center of each tube and the centers of the tubes adjacent thereto is in the neighborhood of one and one quarter times the maximum diameter of the tubes.

4. An economizer comprising a bank of tubes having end portions of reduced diameter and spaced so that the average distance between the center of each tube and the centers of the adjacent tubes is in the neighborhood of one and one-quarter times the maximum tube diameter, and a hous- 879
ing for the bank of tubes comprising a metallic wall through which said reduced tube end portions project, and connections external to said shell be-

tween the reduced end portions.

5. The method of operating an economizer comprising a bank of horizontally disposed tubes connected to provide paths of water flow between the tubes at the top of the bank and the tubes at the

880 bottom of the bank passing successively through intermediate tubes at different levels, which consists in passing heating gases upward through the inter-tube space of the bank, and passing the water along said paths of flow from the top to the bottom of the bank with a velocity of water flow through the tubes in excess of that permitting equalization of temperature in tubes at different levels by convection currents of the water in the tubes.

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per A 6. The method of operating a steam generating unit comprising a boiler section proper and an economizer, which consists in passing all the heat-
881 ing gases leaving the boiler through the economizer under normal and under load conditions, and passing the gases leaving the furnace under peak load conditions partly through the economizer and partly through a by-pass about the economizer.

---

per C *6* ~~7.~~ In an economizer, the combination with an economizer and provisions for passing heating gases through the economizer, of an elongated by-pass for heating gases about said economizer, and

~~-4-~~

a series of dampers distributed along the length of
882 said by-pass and each adjustable from an open position into a closed position in which it substantially obstructs the by-pass but does not tightly
Ins. A4 seal the latter.
(p. 8) *A4*

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per A 8. The improved method of operating a steam operating unit comprising a boiler section proper and an economizer which consists in diminishing the amount of heating gases passing through the

economizer relative to that passing through the boiler section proper under peak load conditions. 883

7 ~~9~~. The combination with a conduit for heating heated gases of means for regulating the flow through said conduit comprising a series of dampers distributed along the length of the conduit and each adjustable from an open position into a closed position in which it substantially closes but does not entirely seal the conduit.

per C

8 ~~10~~. An economizer comprising a casing provided with an inlet and an outlet for heating gases, and two banks of economizer tubes located therein and providing parallel paths of flow for the heating gases between the inlet and outlet and spaced apart from one another to provide between them a by-pass between said inlet and outlet, and means regulating the flow through said by-pass. 884

Ins. A5
(p. 9)

–5–

Oath executed June 26, 1922. No foreign patents or applications recited therein. *New Oath Oct. 27, 1925.*

Paper No. 2. *Sub. Power of Atty.* Nov. 6, 1922.

The undersigned, attorneys of record in the matter of the above identified application, hereby appoints, John E. Hubbell (Reg. No. 5600), of No. 469 Fifth Avenue, New York, N. Y., substitute attorneys, with full power in the premises. 885

Paper No. 3. Rejection Apr. 16, 1923.

This case has been considered.

Page 7, line 2, is "silocel" correct?

Page 9, lines 10 to 16, how can the longitudinal movement of the part E3 be turned into a rotary movement?

886 Page 10, line 11, numeral D16 should be applied to the drawing.

Page 11, lines 5 to 10 should be cancelled as not shown.

Page 12, lines 1 to 7 are not understood. The tubes are spoken of as being, horizontal transverse and parallel to the flow of gas and staggered.

Page 15, lines 18 and 31, "D10" should be –D12–.

Page 17A, line 18 "ases" should be –gases–.

–6–

Claim 1 is rejected on

Rice, 772,059, Oct. 11, 1904, 122–444, in view of

Foster, 744,323, Nov. 17, 1903, 122–367.

887 Rice shows the general layout with an economizer of greater surface than the boiler. Foster shows the specific heater tubes.

Claims 2 and 3 are rejected on

Jacobus, 1,281,016, Oct. 8, 1918, 122–444, in view of Foster, cited. The exact distance between the tubes is merely a matter of selection.

Claim 4 is rejected on

Beha, 726-243 Apr. 28, 1903, 122–444, in view of Foster cited. There would be no invention in using Foster's tubes in Beha's casing.

Claim 5 is rejected on

888 Klump, et al., 1,107,313, Aug. 18, 1914, 122–421. Klump even shows means for recirculating the water through the heater so as to get rapid enough circulation.

Claims 6 to 10 are rejected on

Blossom et al., 712,490, Nov. 4, 1902, 122–421.

All of the claims are rejected and the following art made of record:

Killman, 1,152,421, Sept. 7, 1915, 122–421,

Kablitz, 886,516, May 5, 1908, 122–421.

–7–

Plaintiff's Exhibit 16.

Paper No. 4. *Amendment A & Aff.* *Oct. 8, 1923.* 889

In response to the Office Action of April 16, 1923, I hereby amend the above entitled application as follows:

A¹ & others. *Specification amended as indicated on copy of patent and as follows:* Page 5 of patent, line 88, after "D2." the following was inserted and afterward cancelled:

890

A2 per B

~~To avoid unnecessarily high draft losses and to insure proper contact of the heating gases and tubes, the latter are preferably spaced as shown in Fig. 1, so that the distance between the adjacent outer surfaces of a pair of adjacent tubes in a horizontal row is slightly less than twice the distance between adjacent outer surfaces of adjacent tubes in adjacent horizontal rows of tubes.~~

(p. 2 Abst.) Claim 1, line 2, after "section" insert:

A3 per C

~~having storage capacity for a variable amount of water and having a steam and water separating space~~

Claims 2 and 3 amended as indicated on page 3 of abstract. 891

Cancel claims 6 and 8 and renumber the remaining claims.

(p. 5 Abst.) Claim 6 (original 7) add to the claim as typed before the period in last line thereof:

---

per C
A4

and all cooperating in their closed positions to substantially prevent flow through said by-

per B

~~paths~~

Plaintiff's Exhibit 16.

892 *Insert the following claim:*

9. An economizer having horizontal tubes located
A5 in a duct swept by the heating gases and extending,
per C and arranged in rows extending, in a direction substantially transverse to the direction of heating gas flow, the tubes in adjacent rows being staggered, and being provided with corrugated surfaces to augment the aggregate heating surface, and being compacted
per B so that the average distance between tube centers is in the neighborhood of one and one quarter times the maximum tube diameter, and the tubes being so spaced that the area of the gas path between the two
893 adjacent tubes in adjacent rows transverse to the
per B direction of gas flow is not less than half the area of the gas path between two adjacent tubes in the same transverse row.

In a separate communication instructions are being given the Office Draftsman to apply the reference symbol D16 to Figure 3.

The Examiner's question with regard to lines 10 to 16 of page 9 of the specification is not understood. It is apparent from this portion of the specification as well as from the drawings that the shaft E4 carries worms in mesh with
894 worm gear segments carried by the transverse shafts E2. When the shaft E4 is rotated the shafts E2 are obviously thereby caused to rotate.

The Examiner's requirement for cancellation of line 5 to 10 of page 11 of the specification, or the illustration of the subject matter therein referred to, is believed to be untenable. In this portion of the specification, applicant is merely

stating how his invention may advantageously be used. No useful purpose would be served by illustrating an admittedly

old and well known form of boiler feed controller, and cer- 895
tainly no useful purpose would be served in striking from the specification a statement that applicant's unusual boiler and economizer arrangement permits of the use of a controller commonly used with usual boiler and economizer arrangements. The Examiner will see upon reflection that there is no analogy in this respect, to the ordinary case in which the Office insists upon the illustration or cancellation of an alternative construction described but not illustrated.

In view of the references cited the applicant has withdrawn original claims 6 and 8, and has amended original claim 7 to make it more aptly definitive of the subject mat- 896
ter which it was originally framed to define. These claims and the uncancelled and unamended claims are believed to be clearly allowable over the prior art of record or otherwise known to the applicant and his attorney.

Claim 1 is not met by the reference. The amendment made to this claim is intended to emphasize the fact that the boiler called for by the claim is an ordinary boiler for power purposes. The Rice patent cited against the claim does not disclose an ordinary boiler, or a type of boiler construction designed or capable of use in units of sufficient size for power house purposes. The Rice boiler is not the equivalent in any sense for the structure defined in appli- 897
cant's claim 1 and any correspondence between applicant's construction as set forth in his claim 1 and the Rice structure is fortuitous and without significance. The Examiner

will find when he reviews the case that he has no tangible or reliable basis for asserting that what he regards as the boiler and economizer sections of the Rice patent are proportioned as specified in applicant's claim 1, and that the Rice patent contains nothing whatsoever on which the Examiner can predicate the relative draft losses in different

898 portions of the Rice structure. As a matter of fact the Rice patent does not disclose any means for obtaining a flow of the heating gases through the apparatus, and does not even show an outlet for such gases. The Examiner will hardly contend seriously that the Rice and Foster patents taken collectively, suggest the equivalent of the structure disclosed by applicant and set forth in his claim.

The subject matter of applicant's claims 2 and 3 marks a real and substantial advance in the art. The Examiner in his statement that the exact distance between tubes is merely a matter of selection, apparently assumed and intended to
899 imply that the differences in this respect between the applicant's construction and that shown by the Jacobus patent involves nothing more than a difference in degree.

The general nature of the applicant's invention as set forth in claims 2 and 3 is made plainly apparent it is believed in applicant's specification. The attached affidavit of Mr. Keenan confirms the statements made in the specification and shows very clearly that the difference between the structure as set forth in claims 2 and 3 and in the prior art cited against those claims are differences in kind and not mere differences in degree. By proceeding in accordance with the present invention the applicant has increased the
900 capacity of the economizer per cubic foot of space occupied

by the bank of economizer tubes something like five fold. The examiner will look in vain through the decisions of the Courts of this country in patent cases, to find any case in which a reproportioning and rearrangement of parts giving the advantages approximating those obtained by the applicant was held unpatentable because it involved nothing more than a matter of design or selection.

Claim 4 contains the limitations of claims 2 & 3, and in

addition is limited to features of construction and arrange- 901
ment of the end connections facilitating the close spacing of the tubes and giving other advantages pointed out in applicant's specification. Applicant's attorney is unable to find in the references cited against claim 4 any suggestions of the subject matter of the claim, or any basis for rejecting the claim and if on reconsideration the Examiner is still of the opinion that this claim is unpatentable over the references cited, he is requested to explain his rejection in such manner as to make it clear how he believes the structure of the references might be combined or modified in such manner as to approximate the structure of the claim.

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It is true as the Examiner suggests, that in the Klumph patent means are provided for obtaining a forced circulation of water through the heater, but what has this to do with the patentability of applicant's claim 5? This claim is directed to a method of operation devised to overcome a difficulty experienced in an economizer comprising a bank of horizontal tubes. Klumph does not show an economizer of this type. The problem which the applicant has solved does not present itself in an economizer of the Klumph type, and Klumph does not do what the claim calls for.

Claims 6, 7 and 8 are directed to the means devised by

903

the applicant for regulating the flow of hot gases through a by-path as conduit. On account of the high and fluctuating temperature of the heating gases passing through the by-pass at different times and the dimension of the parts it has heretofore been found difficult to provide a proper damper control for the flow as the damper parts and their seats tend to warp and distort under the conditions of operation. Applicant's solution of this problem as specified in claims 6, 7 and 8 is simple and has been found highly effec-

904 tive and satisfactory in extended commercial use. His arrangement is not employed or suggested in the Blossom patent as the Examiner will find on reviewing the claims in the light of this explanation. The Examiner's attention is directed to the fact that the dampers E1 shown in the Blossom patent which are of a type commonly employed in economizers of the type illustrated in that patent, are not regulating dampers properly speaking, but are exactly what they are called in the Blossom patent, namely, "hinged baffle plates", i. e. deflecting vanes for directing the heating gases into the intertube space of the bank of economizer tubes at
905 the side of which these baffle plates are placed.

New claim 9 is directed to the same subject matter as claims 2 and 3 but contains an additional limitation.

State of New York
County of New York, ss.

Walter F. Keenan, being duly sworn, deposes and says as follows:

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He is of mature age, a citizen of the United States, a resident of Pelham, County of Westchester, State of New York, and is now and has been for several years past, in the
906 engineering department of the Power Specialty Company, at 111 Broadway New York City, and is now Chief Engineer of that Company. He has had many years experience in designing and constructing steam plant apparatus including boilers, superheaters and economizers.

He has examined the above mentioned application of John E. Bell and is familiar with the constructions illustrated and described therein. He has read the Jacobus Patent #1281016 and is familiar with the construction of the economizer designed and built by Jacobus' assignee, the Babcock and Wilcox Company, in general correspondence with the

disclosure of said Jacobus Patent and hereinafter called the Jacobus economizer. 907

The Power Specialty Company has designed and built a number of economizers of the character disclosed in the above entitled application of Bell, and hereinafter referred to as the Bell economizers, and these economizers have given excellent results in use, and have been received with favor by the trade and by the steam engineering profession.

The Bell economizer differs substantially and markedly from economizers heretofore built, including the Jacobus economizer, especially because of the relatively close spacing of the tubes of the Bell economizer, and their corrugated external surfaces whereby the heating gases are caused to 908 flow through the bank of economizer tubes along tortuous passages and with a relatively high velocity and the amount

of gas swept heating surface per cubic foot of space occupied is much greater than in prior economizers. In consequence the Bell economizer is more compact and relatively smaller in bulk per unit of capacity than prior economizers, and it is therefore practically possible to encase the economizer in an air tight metal wall casing so that the unusually high draft suction required to move the heating gases through the economizer can be employed without creating 909 objectionable air leakage and thereby unduly adding to the load on the draft creating motor.

The differences referred to above between the Bell economizer and the economizers of the prior art and particularly the Jacobus economizer, are very striking from the practical standpoint, and seem to deponent to amount to differences in kind rather than to differences in degree. The character of these differences becomes clearly apparent

910 on a comparison of dimensions of the Bell and Jacobus economizers as actually constructed.

In typical Jacobus economizers as actually constructed by the Babcock and Wilcox Company, plain two inch economizer tubes are employed, being arranged in horizontal rows with the tubes in adjacent rows staggered with respect to one another, and with the tube centers spaced three and one half inches apart in the horizontal rows, and with the vertical distance between the center lines of tubes in adjacent horizontal rows equal to five inches. This gives an average distance between the centers of adjacent tubes of

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about four and four tenths inches. The external heat absorbing surface of each Jacobus tube, per foot of tube length is about .525 square feet.

In a typical Bell economizer as actually constructed by the Power Specialty Company, the internal tubes are two inch tubes, but the maximum diameter of each tube casing is four and five eighths inches, and the external or heat absorbing surface of each tube is about three square feet per foot of tube length. In the Bell economizer the tubes are arranged in horizontal rows with the tubes in adjacent rows

912 staggered. The distance between the tube centers in each horizontal row is five and one half inches, and the vertical distance between the tube center lines of tubes in adjacent horizontal tube rows is five and three eights inches, thus making the average distance between centers of adjacent tubes approximately equal to 5.78 inches.

For convenience in comparison some of the foregoing figures and other figures deduced therefrom are tabulated below as follows:

Plaintiff's Exhibit 16.

	Babcock & Wilcox	Bell	
			913
Internal tube diameter	1.70	1.70	
Maximum external tube diameter	2″	4 5/8″	
Average " " "	2″	3 1/4″	
External heat absorbing surface per foot tube length	.525	3	
Average distance between tube centers of adjacent tubes	4.4	5.78	
–16–			
Number of elements per sq. ft. vertical section transverse to the tubes	8.23	4.88	
External tube heating surface per cubic ft. of economizer space	4.31	14.64	914
Minimum cross sectional area of gas path per sq. ft. of horizontal economizer section	.43	.41	

It will be observed that in the Bell economizer, the average distance between the centers of adjacent tubes is in the neighborhood of one and one quarter times the maximum diameter of the tubes. This close spacing not only results in a relatively high external heating surface area per cubic foot of economizer space, but results in paths of flow for the heating gases of relatively small mean hydraulic 915
depth to which the corrugated external surface of the tubes also contributes, and this, as all those skilled in the art know, results in a relatively high heat transmission coefficient. It is not possible from a practical standpoint to space two inch plain tubes as used in the Babcock and Wilcox economizers so closely together that the average distance between the centers of adjacent tubes is only one and a quarter times the tube diameter, for the reason, among others, that in practice adjacent pairs of tubes must be

916 connected into a single header by expanding the tube ends into holes formed in the header. To enable this expanding operation to be carried on there must be substantially more metal in the portion of the header between adjacent tube holes than would exist if the tubes were spaced at an average distance apart of one and one quarter times their diameter. With only one half inch of metal between holes in

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the header, the metal between holes would flow and distort in the expanding operation, making tight points impossible of attainment, as well as making the structure dangerously weak.

917 In practice the capacity of the Bell economizer is about two and one half times that of the Jacobus economizer per cubic foot of space occupied by the tube bank. In economizers of the same capacity the draft loss in the Bell economizer is about double that in the Jacobus economizer.

W. F. KEENAN, Jr.

Subscribed and sworn to before me a Notary Public, this 31st day of August 1923.

D. H. GARDENER

[SEAL] Notary Public.

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918 Paper No. 5. Rejection April 29, 1924.

In response to amendment filed Oct. 8, 1923.

On the drawing a view should be added to show the inlet header D9 and outlet header D10 connected to the 14 pipes D′.

Page 5, line 15, "ocygen" is misspelled.

In the amendment to line 18, page 12, the last 3 lines are incorrect when the tubes are drawn to scale with the dimensions given in the affidavit filed in this case the distance

between the horizontal tubes is not less than twice the distance between adjacent tubes in adjacent rows. 919

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Claim 1 is rejected on Jacobus of record in view of Foster of record or either of the following patents:

Foster, 1,357,493, Nov. 2, 1920, 122–421,

Foster, 1,239,377, Sept. 4, 1917, 122–421.

Applicant has merely substituted the Foster tube in the Jacobus economizer. The ratio between the boiler and economizer as to capacity and relative draught loss is purely a matter of engineering design. However it is old to have the economizer of large capacity. See Killman of record where the economizer is larger than the boiler and one in 920
which the draught loss would be as great as in the boiler.

Claims 2, 3 and 9 are rejected on same references as claim 1. They are also rejected on

DeNaeyer, 365,801, July 5, 1887, 122–421,

in view of any one of the Foster patents as not invention to substitute the Foster tube for the tubes L′ of DeNaeyer. The DeNaeyer economizer shows tubes spaced approximately the same as applicant's. However, it is still maintained that the specific spacing of tubes is purely a matter of engineering design involving nothing more than changes in degree. Further, the last 3 lines are inaccurate as was pointed out in reference to change, made in line 18, of page 921
12.

Claim 4 is rejected on DeNaeyer, cited, in view of Beha of record, as not involving invention to use Beha's casing for DeNaeyer's economizer.

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Claim 5 is rejected on either of the following:

(Br.) Levi 2,097, Feb. 1, 1900, 122–420,

(Br.) Niclausse, 24,162, Dec. 16, 1914, 122–420.

922 These patents both show a down flow of water and Levi shows the pipe *g* leading from the pumps. Here again applicant is merely setting forth a difference in degree as to the velocity of the water flow and even this velocity cannot be definitely ascertained but as applicant points out depends on the design of the apparatus. The claim is also rejected as functional and indefinite.

Claims 6 to 8 are rejected on Blossom of record. The dampers D and D3 are the by-pass dampers that applicant's claims read on. Blossom has a parallel gas flow through his two sections of the economizer and also provides for by-passing the gases during overload operation.

923 In the amendment to last line of present claim 6, "prevent" and "by-pass" are misspelled.

In claim 7, line 2, "heated" should be cancelled.

In claim 9, line 7, "neighborhood" is misspelled and line 10, "area" is misspelled.

Paper No. 6. *Power of Attorney* *Jan. 8, 1925.*

The POWER SPECIALTY COMPANY, a corporation of New York, being the assignee of the entire interest in and to

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improvements in STEAM GENERATING PLANTS, for which

924 JOHN E. BELL, who died November 27, 1924, made application for Letters Patent, Serial No. 572,165 (assignment recorded in the Patent Office in Liner W–117, page 212 of Transfers of Patents) hereby appoints John E. Hubbell, of No. 8 West 40th St., in the City and State of New York, its attorney.

Paper No. 7. *Amendment B* *Apr. 28, 1925.*

In response to the Office action of April 29, 1924, I hereby amend the above entitled application as follows:

Plaintiff's Exhibit 16.

Specification amended as indicated on copy of patent and on page 8 of abstract. 925

Claim 6 amended as indicated on page 8 of abstract.

Claim 9 amended as indicated on page 9 of abstract.

Applicant will be glad to add a view as suggested by the Examiner if upon reconsideration the Examiner still thinks such view desirable and will explain a little more clearly what he has in mind. So far as applicant's attorney can see, the disclosure would not be improved by an additional view.

The insertion made by the previous amendment paper in line 18 of page 12 of the specification, has been cancelled as unnecessary, and because as phrased it was not sufficiently clear and precise. The feature of the tube spacing to which 926

the cancelled insertion was directed which is of real importance, is that the area of the flow passage between each pair of adjacent tubes in adjacent rows transverse to the flow of gases, should be at least as great as half of the area of the flow passage area between two adjacent tubes in the same tube row transverse to the flow of the gases. Claim 9 is in accordance with applicant's drawings, which if made to scale with the tube spacing and dimensions given in Mr. Keenan's affidavit, will show a distance between adjacent 927 tubes in adjacent rows a little greater than the actual difference between adjacent tubes in the same row. Of course, if the diagonal distance is greater than the whole horizontal distance it is greater than half the horizontal distance. The statement that the diagonal distance should not be less than half the horizontal distance, is a statement of a limiting condition which does not need to be realized to secure a tube spacing which is close and in accordance with the appli-

928 cant's invention as compared with the very much more open spacing characteristic of the prior art.

Applicant's attorney respectfully submits that this application should receive a more liberal and sympathetic treatment in the Patent Office than was indicated by the previous Office actions. It is a matter of common engineering knowledge, of which the Examiner is doubtless aware, that the

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so-called Foster economizer, invented by the applicant and disclosed and claimed in this application, has gone into very extensive use, particularly in large station power plants
929 recently erected in this country. The Foster economizer has displaced other economizers and has gone into many installations, where, but for its much greater capacity and better performance as compared with other economizers, there would have been no economizers installed. Mr. Keenan's affidavit explains some of the reasons why the Foster economizer has become commercially valuable and important.

I call the Examiner's attention particularly to the final paragraph of Mr. Keenan's affidavit in which he pointed out that the capacity of the Bell economizer is about two and a half times that of the Jacobus economizer, per cubic foot of space occupied by the tube bank. The Jacobus econ-
930 omizer, built by the B. & W. Company, represents practically the highest standard of comparison to be found in the actual prior art. What authority has any tribunal expounding or applying principles of the patent law of this country to ignore any such important result as an increase of 150% in capacity, or to suggest that this is a mere obvious result of engineering knowledge and design. The Examiner's attention is directed in this connection to the decision of the Supreme Court in Webster Loom Company v. Higgins, 1882 C. D. 285, in which the Supreme Court held in substance

that a mere increase in loom capacity of 25% was presump- 931

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tive evidence that the changes in the loom made to produce this result were not obvious changes, but involved invention. If a 25% increase in capacity created a presumption of invention in the loom case, why should not a 150% increase in capacity in the present case give rise to the same presumption.

As the Examiner is doubtless aware—it is generally known in the engineering world—the applicant, the late John E. Bell, was a great engineer and inventor. Mr. Bell has combined the knowledge and experience of a highly 932
skilled and experienced engineer and scientist with an almost unique capacity for real originality and ingenuity in devising novel and *practically useful* inventions. I believe the Examiner may be interested and find helpful the following letter written to me by Mr. Bell under date of January 31, 1924. This letter was written without specific reference to any particular patent application or Patent Office action.

> "As we go along with our economizer work it is becoming more and more evident that our advantages over the plain tube construction are even greater than we had at first anticipated. As you know, we propose 933
> economizers with induced draft fans in which we take a draft loss through the economizer of anywhere from ½″ to 2″ of water. The cost of the fan blower for 1″

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> draft is compensated for by the increased steam production corresponding to a rise in the feed-water temperature of 2°F. Consequently when we take a draft loss of as much as 2″ all we have to gain, to warrant the expenditure for the fan power, is an increase in

934 water temperature of 4°. As an actual fact with the same heating surface the increase in draft loss from ½″ to 2″ would mean an increase in heat absorption of at least 25%, and for an economizer that would give 100° rise with ½″ draft loss we could easily get 125° rise with a 2″ draft loss. The gain would consequently be more than six times the cost of the power for the fan. With the plain tube economizer the increase in efficiency of the heating surface corresponding to the increase in the draft loss cannot be effected except by shortening the tubes and increasing the length of the gas pass. These economizers at best are high so that
935 if they want to double the draft loss they will have to double a heighth that is already excessive and virtually forces them out of consideration. I say that the only way to increase the draft loss is by such a procedure having in mind that they cannot space the tubes closer together horizontally, if it is a vertical gas pass, on account of the necessity of having proper ligaments between the tube and handhole plates of the headers or connecting boxes.

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The second great advantage lies in the fact that our
936 tubes have six times the external surface for a given length of plain tubes and that we consequently have, comparatively speaking, a great many less tube ends and header or return bend connections with their cost and complication; and what is possibly equally important, we have plenty of room to get these in on account of the wide center to center space caused by the fact that the diameter of our rings on a 2″ tube is 4–5/8″. With the saving in heighth that our construction permits we can go to what consider the max-

imum heighth economizer, which means an economizer 937
with the fewest tubes in width, and consequently we have the minimum number of pipes for carrying the water. As a result when the gases flow upwardly through a vertical economizer and the water down we can obtain a velocity of circulation of the water that is impossible in the plain tube economizer. For this reason the B. & W. Company refuses to quote on economizers with the water passing downward and we, therefore have this great advantage. In some cases our economizers are wider than we think they should be for a down water pass, and when such is the case
we connect the tubes for a back and forth pass in a 938
given horizontal row and cut down the number of channels to one-half or one-third, or even a lesser amount, so that we can always get our velocity up to the point where we are sure there will be no counter-

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circulation in the water. This cannot be done with an economizer in which the tubes are expanded into headers of the full width as in the B. & W. construction and is only made possible with us by the fact that we use individual return bends.

I do not think there is anything new in what I have 939
stated above in the sense that it has not been previously discussed, but I am writing this letter mainly to emphasize in your mind the fact that these advantages are real and are showing up as such in our work."

The letter just quoted is interesting, I submit, not only because of the specific statements and explanations made therein, but because it indicates quite clearly that the practical use of the invention claimed in this case had given

940 advantages greater even than had been anticipated by the inventor at the time he produced his invention.

The Examiner's rejection of claim 1 in the last Office Action is a confession that the references cited against the claim do not anticipate it. The Examiner does not deny the practical advantage and merit of the subject matter of claim 1, but asserts that the ratio between boiler and economizer draft loss, etc. is a mere matter of engineering design. This, I submit, under the circumstances, is not a

proper ground of rejection. The citation of the Killman
941 patent in this connection and in view of the showing of practical merit made by Mr. Keenan's affidavit, is absurd. The structure of the Killman patent is obviously and unquestionably unfitted for use in power plants of the character in which the Foster economizer invented and claimed by the applicant, or the Jacobus economizer, is actually used. There is no suggestion of applicant's structure in the Killman patent, and no sane engineer would consider for a second the possibility of using the economizer of the Killman patent in preference to the applicant's economizer or at all.

Mr. Keenan's affidavit and Mr. Bell's letter quoted above,
942 make it clear that it is physically impossible with the type of construction shown by the DeNaeyer patent cited against claims 1, 2, 3 and 9 to have the amount of heating surface in a given space which is obtainable and is obtained in practice with applicant's construction.

The Foster patent No. 1,239,377 does not meet the terms of any of applicant's claims and shows a structure which would not give the characteristic advantages and results of applicant's constructions, and is principally interesting as showing how non-obvious it was to use Foster corrugated

elements in the proper manner to achieve the results se- 943
cured by the applicant. The economizer of this Foster patent was designed in accordance with the teaching of the practical prior art that an economizer could not be used

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with advantage unless it involved but a trifling draft loss. The Beha patent seems to me to really require no comment because it is so obviously not the equivalent in structure or mode of operation with anything which the applicant is claiming. I note, however, that the Beha construction involves a weight of cast iron altogether out of proportion to the area of heating surface provided to make it comparable 944
with the applicant's apparatus or feasible from the standpoint of cost.

All that the references cited against claim 5 show is that proposals have been made in the past to use economizers in which the water flows successively back and forth through horizontally disposed tubes located at successively lower levels. Claim 5 does not call for the structures shown in the prior patents, but for a mode of operation which would make such economizers practically useful as they were not prior to the applicant's invention. I ask the Examiner to note Dr. Jacobus' patent No. 1,472,474 applied for before, and granted after the filing of this application. In this 945
patent Dr. Jacobus, who is perhaps the best known boiler engineer in the world, provided a complicated economizer arrangement so as to approximate the desirable counterflow condition in an economizer in which the heating gases flow upward without requiring the water to flow successively through tubes at successively lower levels. Dr. Jacobus did this, as his specification sufficiently indicates, be-

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cause economizers of the type in which the water flow is

946 downward were not regarded as satisfactory. The applicant discovered why such economizers heretofore have not been practical, and in his application tells how to avoid this defect. There is, I submit, nothing uncertain or indefinite in the statements made in the applicant's specification concerning the manner in which the invention of claim 5 is to be practiced. Of course, the critical velocity depends upon the design of the particular economizer with which the method is carried out, and cannot always be readily calculated, but for any given design it is easy to determine this by experiment or by the use of experimental data. Both
947 with regard to the patentability of the method itself and to the sufficiency of the disclosure, I call the Examiner's attention to the decision of the Supreme Court in Eibel Process Company v. Minnesota and Ontario Paper Company, 43 S. C. 322, 310 O. G. 3. In that case the essence of the invention was the pitch or inclination to the horizontal of the pulp screen. The Supreme Court in that case found a relatively slight difference in the angle of inclination to constitute the important invention. The Supreme Court, moreover, sustained the claims over the objection that they were vague in specifying the inclination as "substantial" or "high", and pointed out that such terms were sufficiently
948 definite since the principle of the invention was explained

in the specification, and differences in varying conditions of operation made it difficult for the patentee to say precisely what the inclination should be for a given condition of operation.

The Blossom patent does not meet the applicant's claims 6, 7 and 9, in terms or in substance for the dampers D and D3 are not in series in a single by-pass or gas passage as specified in these claims. With the dampers D and D3 both

closed, as shown in Fig. 1 of the Blossom patent, the damper 949
D is between the outlets B of one group of boilers and the stack connection A, and is subjected to a pressure differential corresponding to the draft loss in the economizer section E. Similarly the dampers D3 are between the outlets B2 from the other boilers and the stack connections, and is subjected to a pressure differential corresponding to the draft loss in the economizer section E2. The dampers D and D3 are really in parallel gas passages and each is subjected to the full pressure differential or draft drop between the stack connection and outlets of the group of boilers with which it is associated. What happens when the dampers
D and D3 are opened is obviously inconsequential. What 950
Blossom really has, so far as the dampers D and D3 are concerned, is a separate by-pass about each of two economizers in conjunction with other elements by which the two economizers may be connected in series or in parallel. There is no suggestion in the Blossom patent of the struc-

ture to which applicant's claims 6, 7, 8 and 9 are directed.

In closing, I ask the Examiner, in his reconsideration of this application, to bear in mind that the real test of invention in this case is the advantages actually obtained by the
use of the combinations and method claimed, and not the 951
so-called obviousness of substituting one mechanical element or expedient. The question is not whether the mechanic would have to exercise the inventive faculty in following his instructions if told to replace the plain tubes of the Jacobus economizer with the tube having a circumferential corrugated cast iron casing, but is rather the originality and merit involved in the conception that by the use of the old Foster elements in place of the old plain tubes in the manner disclosed and claimed by the applicant, a radi-

952 cally new, practical and sucessful form of economizer (characterized by the capacity per volume of space occupied, 25% of that before possible) could be produced.

Paper No. 8. Rejection Aug. 29, 1925.

Responsive to amendment filed Apr. 28, 1925.

Claim 1 should be amended by changing the expression "sections so spaced and" to –sections, said tubes being so–, and by changing "requiring" in line 13 to –so spaced as to require. The claim has been considered in the light of applicant's argument, and is not considered as properly defin-

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953 ing his invention, since the alternative expression "or greater" in line 12 is such a broad term that the heating surface of the economizer tubing might be made many times greater than the heating surface of the boiler thus, according apparently to applicant's arguments, changing the increased efficiency which applicant states results from his invention. The claim is rejected.

Claim 2 is not considered as defining any invention over FOSTER, of record. The relative spacing apart of the heating tubes under the conditions stated by the claim does not necessarily make for any increase in efficiency over the

954 showing in Foster, since it would appear that the amount of metal and the acuteness of the angle between the faces of each rib would be factors in determining the efficiency of the economizer. It is to be noted in claims 2 and 3 that the boiler is ignored altogether, but applicant's arguments suggest that certain proportions must be observed between the boiler and the economizer in order to effect the efficiency applicant claims.

Claim 4 is rejected on FOSTER. There is as much propriety in stating that the "ends of his tubes which project through the wall are reduced" as there is in the case of ap-

plicant's structure. The claim is nowhere supported in the 955
case by any statement that by merely spacing the center of each tube the distance mentioned from the center of its neighboring tubes the efficiency mentioned in applicant's arguments is obtained regardless of the conformation of the respective tubes.

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Claim 5 is not supported by any argument or statement in the case that, by the method therein described and regardless of the extent of the heating surface of the economizer as compared with the extent of the heating surface of the boiler, the efficiency applicant claims to secure may be obtained. The claim is, therefore, rejected as covering what 956
at best amounts to a mere change of speed in the operation of an economizer which operation applicant in his argument on claim 5 confesses to be old; attention being called to the first six lines of page 7 of the above entitled amendment.

Claims 6 and 7, as amended, do not seem to avoid BLOSSOM, who shows a series of dampers at E.

Claim 8 appears to be allowable.

Claim 9 is not understood. The expression "tube centers" in lines 6 and 7 would be satisfied by any two tubes no matter how widely separated. The word "compacted" in line 6 has no definite meaning as used, and it is noted that if ap- 957
plicant contemplated making all the tubes of uniform construction, the claim does not bring this out. At best, the claim does not seem to be patentable over JACOBUS, there being no invention in providing in his economizer a vertical series of tubes similar to and placed alongside of the series he shows, the economizer casing being enlarged for the reception for such additional series of tubes. In the absence of any information derivable from applicant's arguments and specification it is not seen that the dimensions of the

958 various tubes and the spacing of the same amounts to more than mechanical skill.

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Claim 8 appears allowable, but the others are rejected.

In further prosecution of the case applicant should bear in mind insofar as the showing in his arguments and specification is concerned, the efficiency he obtains is due to the dimensions of the heating surfaces of the economizer relative to the corresponding boiler surface dimensions, and apparently when the boiler and its dimensions are omitted, he can not predicate patentability on the relative dimensions of the remaining parts of his organization.

959

Paper No. 9 *Amendment C* *Oct. 27, 1925*

In response to the Office action of August 29, 1925, I hereby amend the above entitled application as follows:

C1–C2 & others.	*Specification amended as indicated on copy of patent.*

Cancel the present claims and insert in lieu thereof the following:

C3 1–8.	*See claims 1–8 of patent without change.*

By the foregoing amendment, the claims have been revised and restricted to put them in a form which the Examiner
960 intimated in a recent interview would render them allowable. For convenience, all the claims have been incorporated in this amendment, although no change has been made in former claims 5 and 8, which in the amendment are numbered

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5 and 7 respectively.

New claim 1 differs from former claim 1 by incorporating the amendments suggested by the Examiner in the last Office action, and by eliminating the words in the former claim "or greater", which the Examiner regarded as objec-

tionable. New claim 2 is directed to the same subject matter as former claim 2, but is couched in different phraseology, and in its present form specifies the great increase in external tube surface per unit of volume of space occupied over prior practice, which is a distinguishing characteristic of applicant's invention. New claim 4 is directed to subject matter for which a claim has heretofore been made in the applicant's earlier application Serial No. 336,284. At the interview referred to, it was agreed that this claim preferably should be made in the present application rather than in the earlier application. 961

The arguments and explanations made to the Examiner in the last interview included nothing not heretofore appearing in the record of this application except certain statements negativing the conclusion that the subject matter of claims like applicant's claims 2, 3 and 4 represent nothing more than obvious and non-inventive utilization of known expedients in the prior art. Those statements were in substance as follows: Applicant's assignee, the Power Specialty Company, has been making the Foster superheater for ap- 962

proximately a quarter of a century. During the years immediately preceding the development of the economizer which is the subject of this application, the sales of the Foster superheater amounted to something like $2,000,000 per annum. The Foster superheater, as all the world knows, comprises steel tube elements encased in externally corrugated tubular casing sections of cast iron. If the desirability and practicability of using such tubular elements in an economizer were obvious, that obviousness should have been apparent to the whole steam engineering world, because the knowledge and use of Foster superheaters was world wide; and should have been especially apparent to the 963

964 Power Specialty Company, which built and sold the Foster superheater, and was, moreover, the owner of the Foster patent No. 1,239,377.

The history of the development and use of the new economizer seems to conclusively negative any presumption that the economizer improvements invented by Mr. Bell and claimed in this application were obvious. When Mr. Bell, who at the time was retained by the Power Specialty Company as a consulting engineer under a very substantial annular retainer, announced to the Power Specialty Company that he had invented a new economizer embodying the use of the externally corrugated elements such as were used in
965 the Foster superheater, and explained his ideas about this economizer to the officers of the Power Specialty Company, the latter entered into a contract providing for substantial

royalty payments to Mr. Bell, and, in the event of his death, to his estate, for a period of many years. Under that agreement, royalties are being paid to Mr. Bell's widow at the rate of many thousands of dollars per year, because the economizer has gone into extensive use and a large annual output is now being sold. While the new economizer is substantially more expensive to build per unit of volume of space occupied,
966 its much greater capacity per unit of space occupied as compared with the ordinary smooth wall economizer which it is replacing, the new economizer is inherently less expensive to produce per unit of water heating capacity than the older form of economizer in general use.

As was explained to the Examiner at the last interview by Mr. Keenan, Chief Engineer of the Power Specialty Company, the compactness of the new economizer, which is practically always advantageous, is so marked in comparison with prior economizers as to permit of the effective use of

the new economizer where conditions make it quite impos- 967
sible to use the older forms of economizers. The Examiner will recall Mr. Keenan's statement that the New York Steam Corporation was recently confronted with the necessity for materially increasing its output. The power plant of that corporation is in downtown New York, where land values make space economy important, and its existing plant, which

–38–

included boilers located at superimposed levels, was so crowded that it was physically impossible to equip those boilers with ordinary economizers, and the owners of the plant were considering the purchase of the additional boilers 968
required to increase the steam output of the plant 50%. They eventually decided, however, to add the claimed economizers to the existing plant, as those economizers were sufficiently compact to go into the very limited space available. As a result of the incorporation of the economizers, the steam output of the plant has been increased 50%, and at the same time the thermal efficiency of the steam generating units has been increased.

In Mr. Keenan's affidavit already on file, it is pointed out that in a commercial form of economizer constructed in accordance with the present invention there is over 14½ sq. ft. external tube surface per cubic foot of space occupied, 969
while in what is probably the best practice of the prior art the external tube surface area is less than 4½ sq. ft. per cubic foot of space occupied. This difference is a difference in kind and not in degree, and the fact that the new economizer because of its compactness can be used with advantage under conditions which do not permit the use of the economizer of the prior art, constitutes a new and useful result of such an important character as to create a presumption that the new construction is the result of invention rather

970 than mechanical skill. The mere increase in capacity per

–39–

unit of space occupied is of itself sufficient to justify the allowance of applicant's broader claims under the doctrine of the Supreme Court in the Loom case, 1882 C. D. 285. The more general claims all clearly distinguish in terms, as well as in substance, from the prior art. The length of the economizer tubes shown in the Foster patent No. 1,239,377, is not many times the tube diameter as specified in applicant's claim 2, and there is not the slightest suggestion in the Foster patent of Mr. Bell's bold conception of greatly in-
971 creasing the amount of heating surface in a cubic foot of space occupied. On the contrary, the economizer of the Foster patent apparently followed the current practice of the prior art of intentionally spacing economizer tubes so openly that the economizer would not materially increase the draft requirements of the boiler furnace with which it was associated. The distinguishing characteristic of the economizer of patent No. 1,239,377, as Mr. Foster set forth in that patent, was the use of tubes of copper or brass, which would not be corroded by the water passing through them, coupled with a tubular cast iron casing to protect the copper and brass tubes from attack by the furnace gases.

972 It was made apparent to the Examiner at the interview referred to that, while the features of economizers construction referred to in present claims 2 and 8 are useful in the combination of claim 1, they are also useful in other relations, so that it is neither necessary nor desirable that all

–40–

of the claims should be limited to use in the combination to which claim 1 is directed.

With regard to claim 5, the Examiner's attention is called to the argument and explanations made in the previous

amendment paper, which, in conjunction with the statements 973
in the specification, clearly bring out the fact that a new, useful and non-obvious advantage is obtained by making the water velocity through the economizer tubes exceed the speed below which temperature equalization of the water will occur in the tubes as the result of gravity circulation. There is nothing vague or nebulous about claim 5, and no real uncertainty as to what must be done to obtain the advantages which the method gives. In view of the statements made in the specification, it is perfectly clear that the critical water velocity in any given economizer may be determined by the simple expedient of measuring the water tem-
perature in the tubes at a point adjacent the top of the tube 974
bank and a point adjacent the bottom of the tube bank and then gradually increasing the water velocity until a sharp variation in the two temperatures occurs.

New claim 6 clearly distinguished from the Blossom patent by specifying applicant's relative arrangement of chambers with respect to a conduit having imperforate walls. In the Blossom patent, the series of dampers E′ which the Examiner had in mind in his reference to this patent in the last Office Action are mere deflecting vanes which divert

–41–

the heating gases into the intertube space at one side of the 975
dampers. Insofar as the dampers E′ are located in a conduit, one side of that conduit is not imperforate, but, on the contrary, is formed by open-spaced tubes.

An allowance of the application as amended is respectfully requested.

OATH.

State of New York

County of New York ss:

Lola R. Bell, being duly sworn, deposes and says that she is the Executrix of the Last Will and Testament of John E.

976 Bell, deceased, who made the above entitled application for Letters Patent, and that she is informed and believes that the subject matter of the attached amendment was part of the invention of the said John E. Bell set forth in said application was invented before he filed his original application Serial No. 572,166; was not known or used before his invention; was not patented or described in a printed publication in any country more than two years before his application; was not patented in any foreign country on an application filed by himself or his legal representatives or assigns more than twelve months prior to his application;
977 was not in public use or on sale in this country more than two years before the date of his application, and has not been abandoned. LOLA R. BELL.

Sworn to and subscribed before me this 24th day of October, 1925.

–42–

Raynond M. Lowes
Notary Public

Notice of allowance dated October 31, 1925.

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978

Dpts 4. A
11-14

THE FOSTER ECONOMIZER

POWER SPECIALTY COMPANY

FOSTER EXTENDED SURFACE

BULLETIN EC 100

THE FOSTER ECONOMIZER

For recovering waste heat
from boiler flue gases

POWER SPECIALTY COMPANY

PHILADELPHIA
SAN FRANCISCO

BOSTON
CHICAGO

DETROIT
DALLAS

PITTSBURGH
KANSAS CITY

General Offices: 111 Broadway, New York

LONDON: Power Specialty Co., Ltd., 315 Oxford Street, W. I.

Works: Dansville, N. Y., and Egham, England

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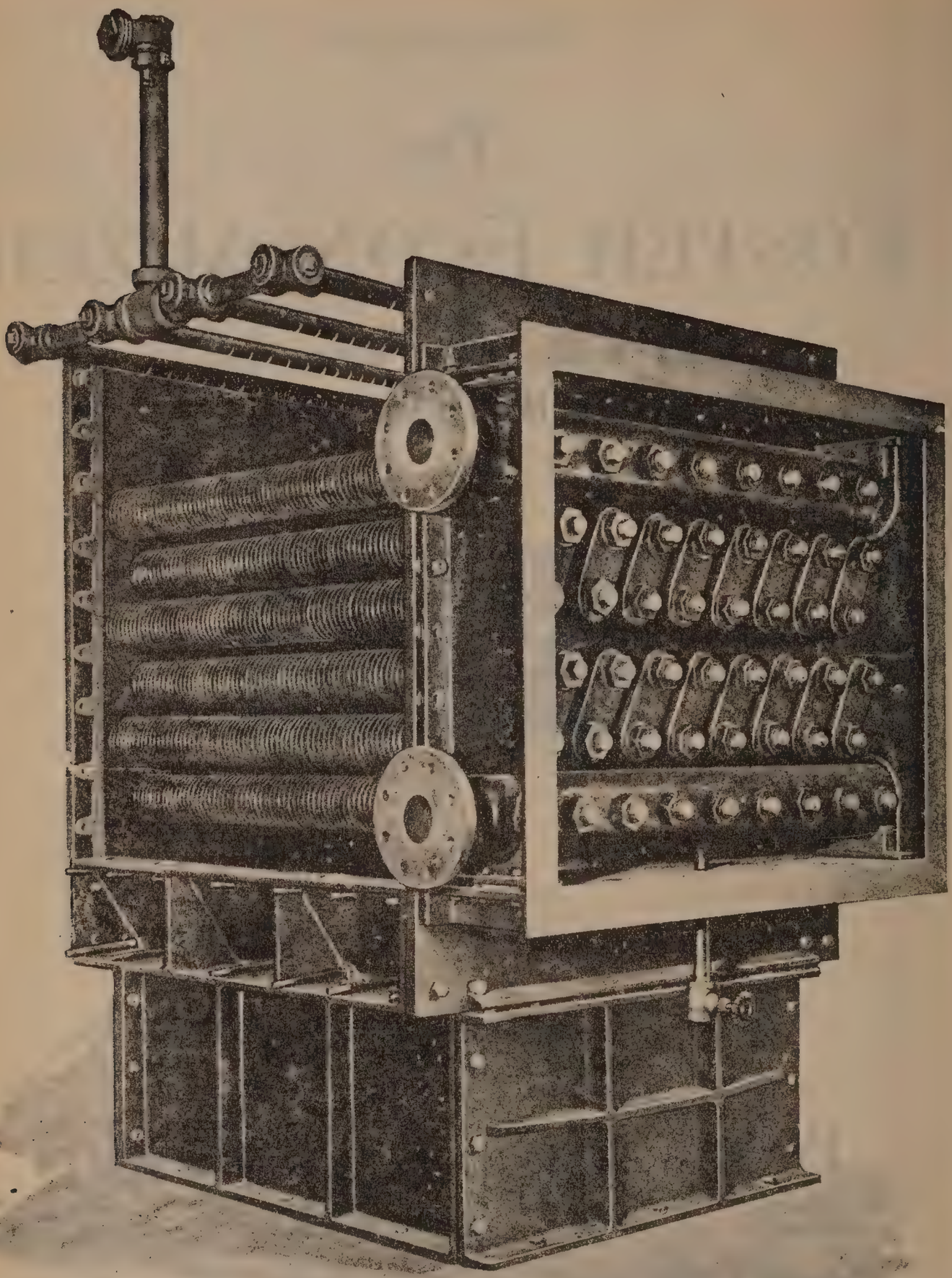

Foster Economizer with side plates and end doors removed and without insulation in place. Showing arrangement of pressure parts, washing piping and housing

THE following pages include a general outline of the development in economizer practice and a detailed description of the construction of the pressure parts and housing of the Foster Economizer and its simplicity of operation. We have also included illustrations of typical arrangements permitted by the great compactness of this apparatus and test data showing the performance of a few of the economizers in service.

No booklet of this size, however, can cover all of the problems incident to economizer installations. It is earnestly recommended that engineers interested in the recovery of the greatest waste now encountered in the boiler room—due to chimney losses—advise us of their problems, giving us the information tabulated on the last of these pages. We will be glad to give our individual attention to all such inquiries.

POWER SPECIALTY COMPANY

The Economizer and its Development

AN economizer is a device for saving fuel by pre-heating the water fed to a boiler by means of the waste gases exhausted by the boiler. Economizers have been used abroad and in this country for more than seventy-five years. During this exceptionally long period it has been conclusively proven that greatly increased efficiencies may be obtained by their use.

In the last few years, however, the increased cost of fuel has created a renewed interest in economizers and has made their use advisable for installations in which, formerly, they would not have been favorably considered. The higher steam pressures under which the modern boilers are operating and which, other conditions remaining the same, result in higher flue-gas temperatures are an added inducement for the use of economizers. The greatly increased popularity of the economizer influenced the Power Specialty Company to investigate the subject and conduct experiments which have resulted in offering the Foster Economizer for steam power plant use.

Careful study and thorough investigation of numerous installations convinced the present authorities on boiler room practice that even better results than had been obtained from economizers in the past could be effected by eliminating the infiltration of air in the economizer itself and in the flue between the boiler outlet and the economizer inlet, and by fully insulating the economizer and the flue connection to reduce the radiation losses.

This thought led to the consideration of an individual economizer for each boiler. The advantages of this type were at once apparent. It was possible to house the boiler and the economizer unit in substantially a single setting. The above losses were reduced to a minimum and the performance of the economizer was completely identified with the individual boiler which it served. Thus as the boiler evaporation is increased, the work done by the economizer is proportionately increased because of the higher gas temperatures entering the economizer, and a high efficiency of the combined unit is automatically maintained over a wide range of load. Because of these marked advantages the Foster Economizer is designed to operate only as a unit in conjunction with an individual boiler.

Furthermore, it was felt that great improvement in economizer construction could be effected by reducing the space required for the economizer and by using a more dependable means of keeping the heating surface clean than had been previously adopted. The Foster patented corrugated surface permits unprecedented compactness of construction and also adapts itself to being cleaned by water sprays, which is the simplest possible method of cleaning any heating surface, and it therefore obtains both of these desired improvements.

While the term "Economizer" is used to describe the Foster surface that adds heat to the feedwater by utilizing the boiler waste gases, the Foster equipment is more of a "Pre-boiler" or a "Flue feed-heater" than an "Economizer" in the sense that the term has been used for so many years. "Pre-boiler" or "Flue feed-heater" more properly indicates the function of the Foster Economizer as distinguished from the designs previously used, but as the principal functions of the old forms of economizers are obtained by the Foster apparatus, the term "Economizer" has been continued.

Relative Size of Economizer

THE Foster Economizer should not be considered as an accessory boiler room equipment but as economically replacing the inefficient parts of the boiler surface. The principal work in a boiler is done in the first pass and the latter half of the average boiler is comparatively inactive because a high rate of heat transfer is prevented by the slight difference in temperature between the water at the point of evaporation and the gases after they have done their major work. The Foster Economizer, however, operating under complete counter-current becomes a superior medium for recovering the heat in the comparatively low-temperature gases.

The development of the modern economizer has, therefore, partially changed some of the principles of boiler design. Attempt is no longer made to reduce the gases to the lowest point possible with little regard for the amount of boiler surface required to do this. The present idea is to design a boiler so that all of the surface will be subjected to a sufficiently high temperature difference to permit every part of it to do a proper amount of work. This scheme contemplates the gases leaving the boiler at from 50 to 100 deg. higher than they formerly did. These hotter gases are then more efficiently reduced in the counter-current economizer to from 200 to 300 deg. lower than possible in the boiler. The effect of this is an increase in the overall efficiency of the unit of from 5 to 10 per cent.

Although more water is evaporated in a boiler served by an economizer than in one with no economizer, the heat transfer through any part of the boiler is not necessarily increased. The greater capacity obtained results from the heat added to the water in the economizer before the water enters the boiler. No more coal need be burned on the boiler grates than without the economizer, and the increased capacity, therefore, may be obtained, together with the increased efficiency, without any additional thermal strain on either brick work or boiler heating surface.

The amount of economizer surface to be installed under given conditions is determined entirely by the load on the plant and the cost of fuel. In some cases it may be advisable to reduce the temperature of the gases leaving the economizer to as low as 250 deg. fahr. Under other conditions of load and fuel cost it may not be found advantageous to install surface that will reduce the gases below 350 deg. fahr.

It has been the general practice in this country to install economizers having from 60 to 80 per cent of the boiler heating surface, and in some installations the economizers have been larger than this. Abroad, however, economizers are in satisfactory operation containing 100, 150 and even 175 per cent of the boiler surface.

The size of an economizer should not finally be decided until the performance has been calculated for the maximum load under which the unit may operate, as it is not advisable to have the economizer so large that it will generate steam under peak loads. There are however, other factors that must be considered before the proper amount of economizer surface can be determined. The information necessary for the intelligent survey of any economizer installation is given on page 32. It is important that all of the data as specified be obtained before a detailed determination can be reached. The above, therefore, should be considered only for general guidance.

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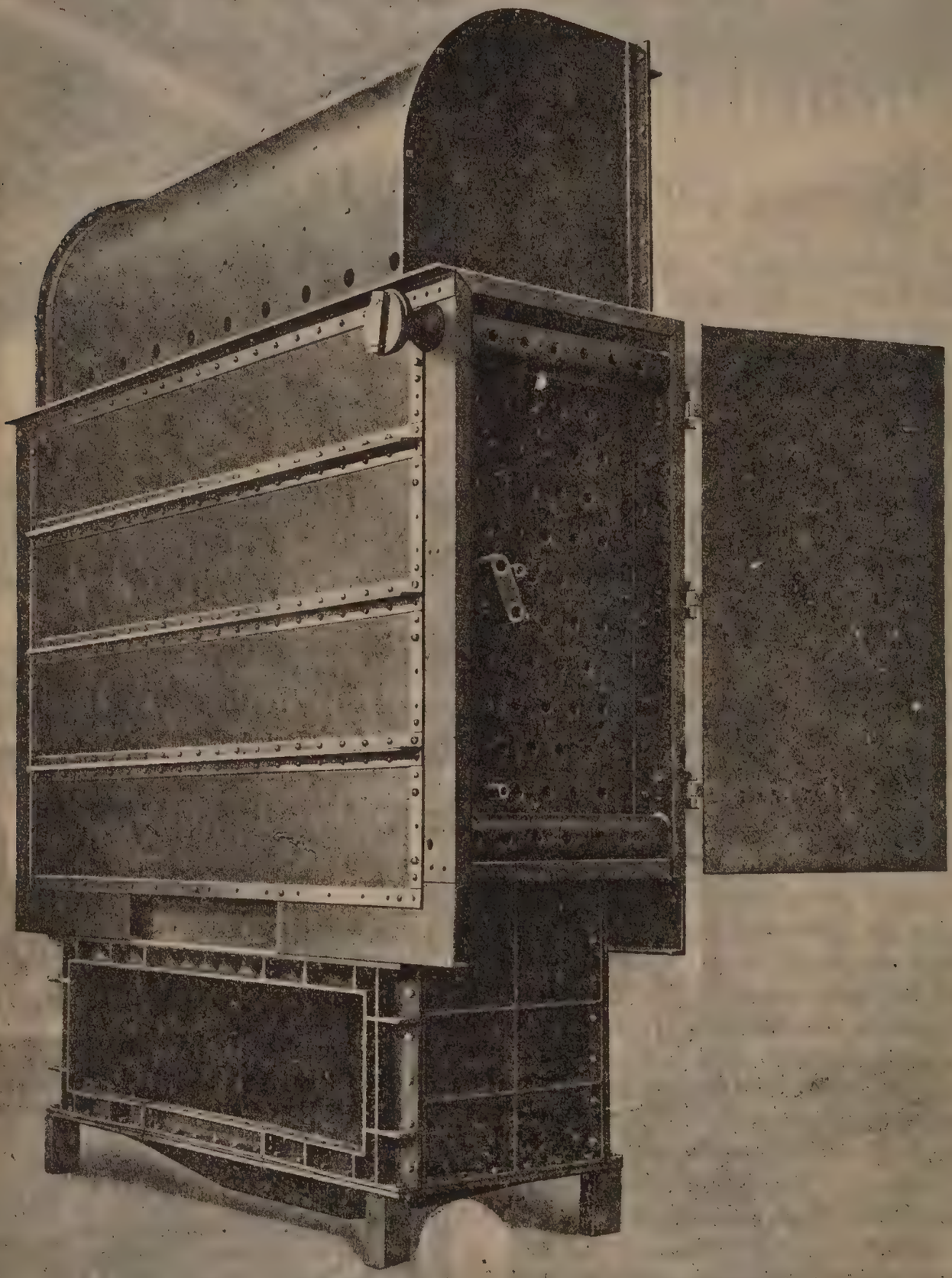


Steel housing and cast-iron end plate of a one-pass Foster Economizer. Photo taken in the shops during erection after inlet and outlet manifolds were in place but before installation of the heating elements and return headers

Cast-Iron and Steel Housing

THE housing for the Foster Economizer consists of an internal and external casing between which insulating material is solidly packed.

The inside casing is constructed entirely of cast iron to resist the corrosive action of the furnace gases and the effects of the water used for washing the heating surface and is formed of a series of end and side plates.

The cast-iron end plates have bee described on a previous page. Thes are supplemented by intermediate cast iron tube sheets if the length of th elements warrants additional suppor

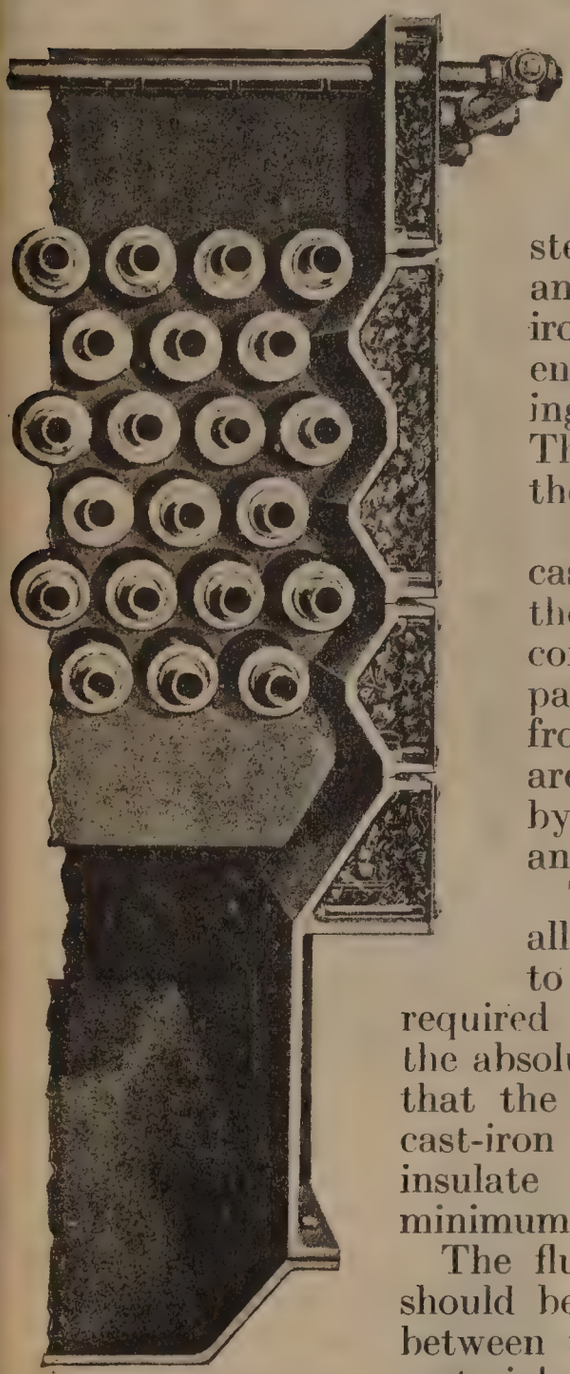
The interior cast-iron side plates c the economizer housing are corrugate to prevent any laning action of th gases or washing water along the sid walls and to insure the proper distribu tion of gases through the heating surfac These plates are flanged and the edges machine and they are rigidly bolted to each other an to the cast-iron tube sheets thus forming casing of extreme strength and stiffness.

The external side plates are constructed of shee steel of the proper thickness to prevent warpin and to insure durability and are bolted to the cast iron casing in sections. The exterior casing at th ends is formed by sheet-steel doors to permit inspect ing all the expanded joints of the pressure parts These doors also protect the insulation packed betwee the return headers and the cast-iron end plates.

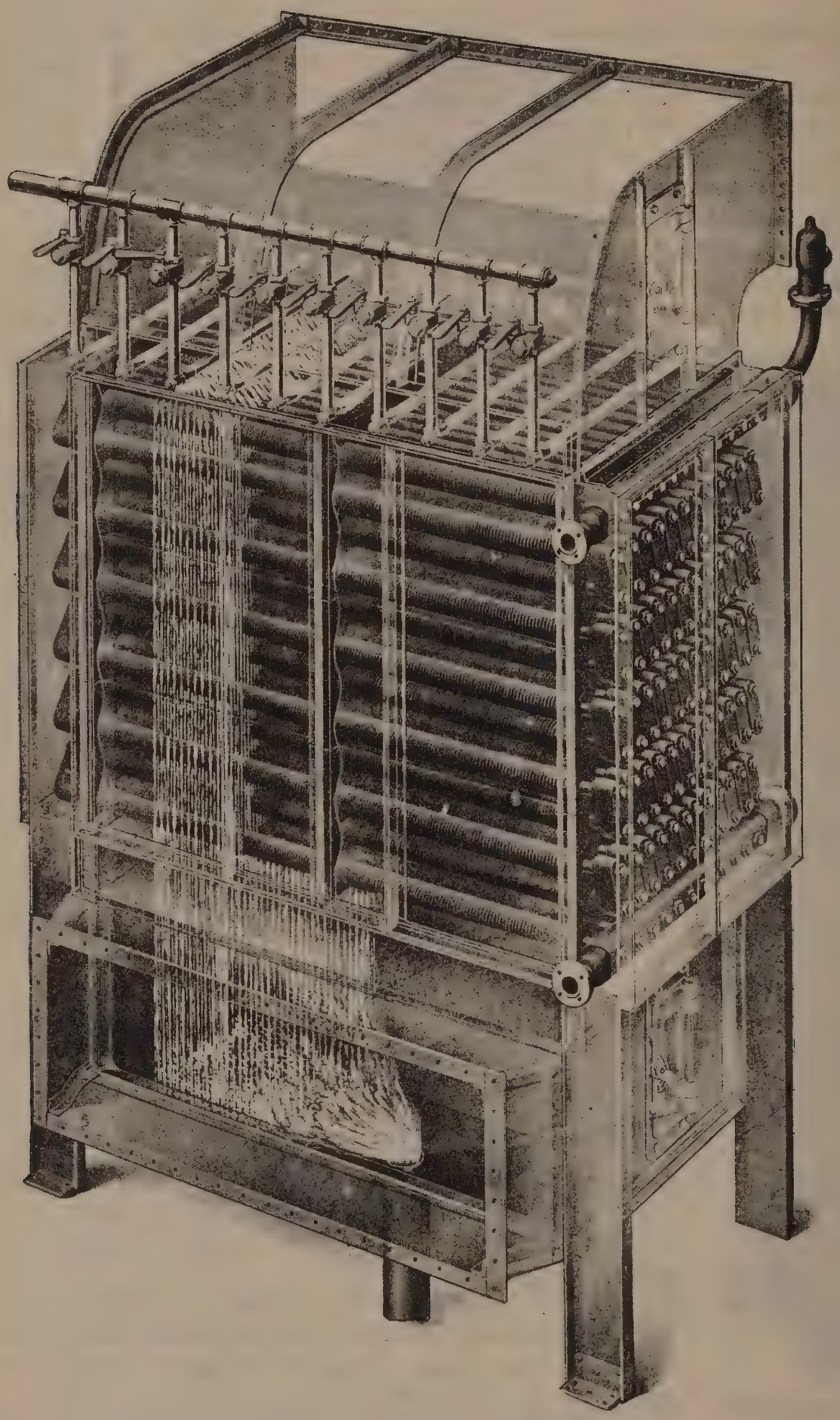
The bottom of the Foster Economizer consists o cast-iron pans. These pans are designed to catc the water used for cleaning the heating surface an conduct it to drain pipes. The castings forming th pans completely protect the supporting steel wor from the corrosive action of the washing water an are connected together and to the economizer housin by accurately machined joints which are watertigh and also prevent air infiltration.

The housing supplied with the pressure parts o all Foster Economizers is complete from the inle to the outlet flues and no brick work or masonry i required in connection with it. The features aimed at ar the absolute prevention of air infiltration and the assuranc that the washing water will come into contact only wit cast-iron surfaces. Further, great care is taken to s insulate the casing as to reduce radiation losses to minimum.

The flue from the boiler outlet to the economizer inle should be built of two thicknesses of steelplate. The spac between these plates should be solidly filled with insulatin material to prevent radiation losses and the joints in thi flue should be carefully made to eliminate air infiltration



Showing construction of the housing



Phantom view of the Foster Economizer showing the action of the washing water

Method of Cleaning

WASHING with water is the simplest and most effective method of cleaning any heating surface. Provision, however, must be made to distribute the water over all parts of the surface and to prevent its injuring any part of the setting. The corrugated external surfaces of the Foster patented element may be thoroughly cleaned in this way and this is one of the greatest advantages of this construction. Each economizer is equipped with permanent spray pipes placed above the top row of elements and perpendicular to them. Each group of these spray pipes is controlled by a quick-opening gate valve which connects to the washing-water header. This arrangement permits the easy admission of water into any spray pipe desired. Cross slots are cut in each spray pipe so that water passing through these falls directly on each of the elements in the top row.

In practice the economizer is washed down while in service, at intervals of once or twice in twenty-four hours and the process takes but a few moments. The water is admitted into only one group of spray pipes at a time and flows down over one row of tubes after another, the corrugations always keeping the water in the vertical plane from which it started. This insures a compact body of water covering even the lowest tubes in the bank and also prevents the water from spreading longitudinally along the tubes and unduly congesting the draft. All the heating surface is, therefore, kept free from soot and dirt and the material removed is carried into the cast-iron pans forming the bottom of the economizer casing and thence to the drain pipe.

While it is necessary to maintain sufficient pressure in the washing-water header to insure an ample supply during the cleaning period, the pressure is not depended on to remove the residue of combustion. The volume of water carried downward by gravity floods the soot from the elements instead of the velocity of the water striking the dirt from the surface. Ordinarily the pressure in the water main is sufficient for the washing supply and this is used at the main temperature.

A decided advantage of using water to wash the heating surface of the economizer is the complete prevention of pitting by the sulphuric content in the furnace gases. While dilute sulphuric acid is known to be an active corrosive agent, the amount of water admitted during the washing process is so great, in comparison to the quantity of acid formed, that it completely flushes the acid away. When the washing process is completed the temperature of the gases in all parts of the economizer chamber is sufficiently high to immediately evaporate the residual moisture and the surfaces are, therefore, left not only clean and dry but free from the dangerous effects of acids.

The illustration on the opposite page shows the performance of the washing water while one of the spray pipes is in operation. Altho a portion of the heating surface is being thoroughly washed, the water offers no interference with the passage of the gases through the remainder of the economizer chamber.

The heating surface is entirely covered with cast iron and the tube sheets that support the elements as well as the interior lining of the side walls are all of this material. The washing water, therefore, comes in contact only with cast-iron surfaces. The inner casing is built watertight so that all of the washing water is conducted down the drain piping.

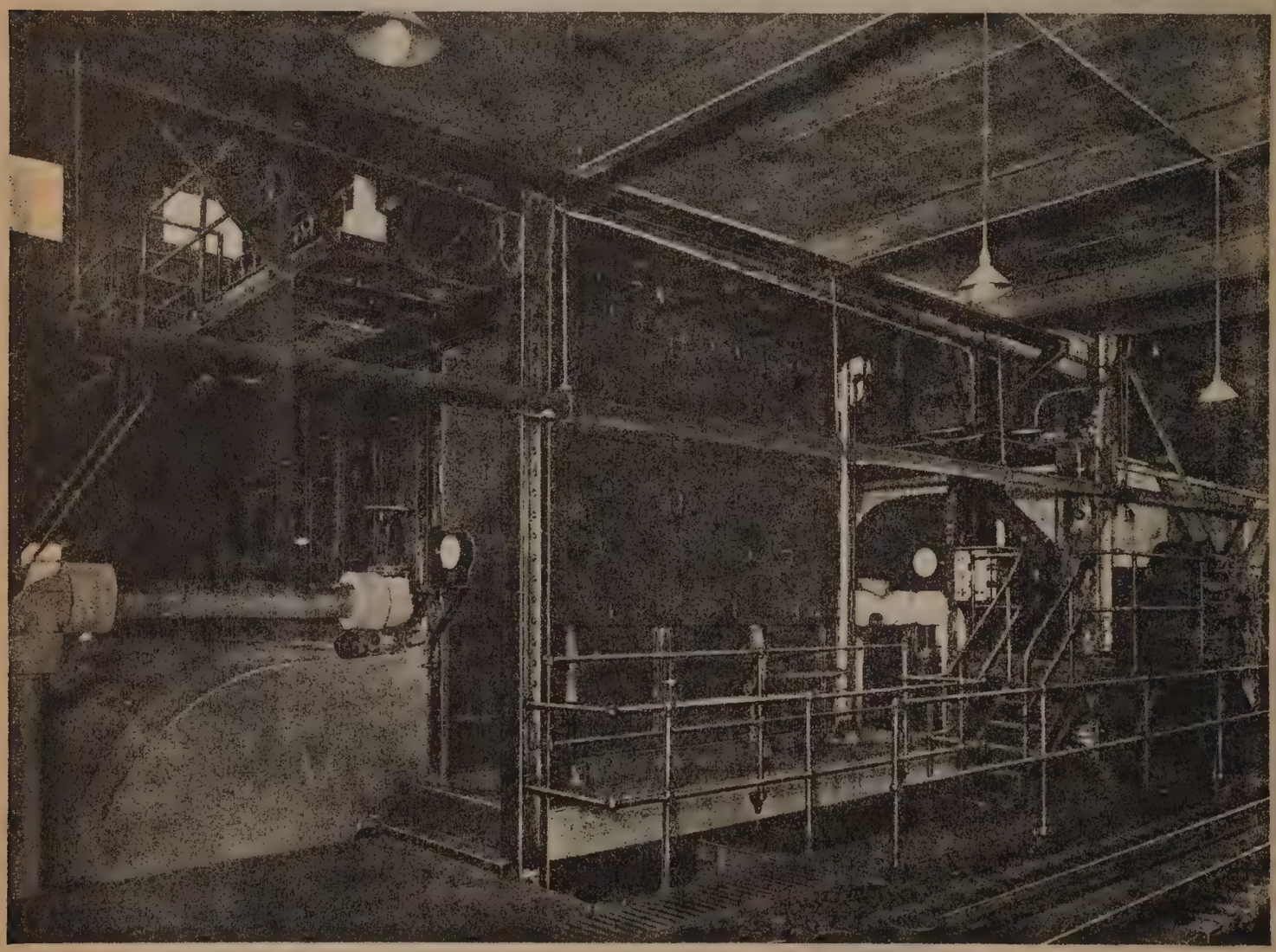
The Advantages of Induced Draft

POWER-PLANT Engineers are now giving favorable consideration to induced draft fans in any type of boiler room because of the greater control of combustion possible by their use, and also because overloads may be carried even though gas areas are reduced by the boiler tubes becoming slagged.

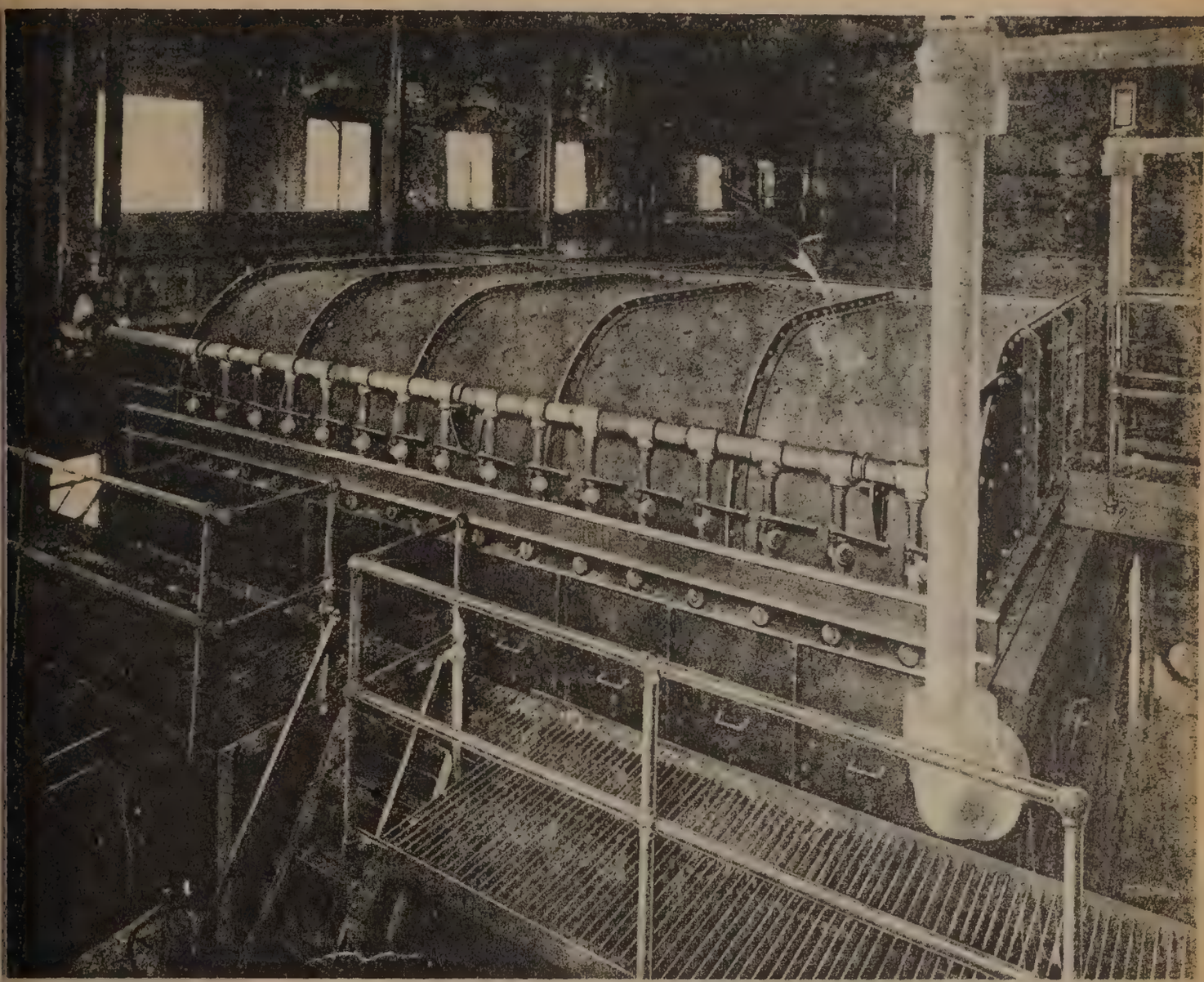
The initial cost of the fans together with the driving mechanism and supporting steel work may be largely offset if not entirely counter-balanced by the saving in cost of the shorter chimneys which may be used. The operating cost of the fans may frequently be entirely disregarded if the exhaust steam from the fan engine or turbine can be used in an open feed-water heater.

In waste-heat utilization it is now the recognized custom to use induced draft equipment to obtain the high gas velocity essential for the efficient utilization of the heat. The Foster Economizer is therefore designed to operate under as high a draft loss as may be found reasonable under the load conditions. The resulting friction loss should be carried by an individual induced draft fan.

It is recommended that no bypass flue be erected around the Foster



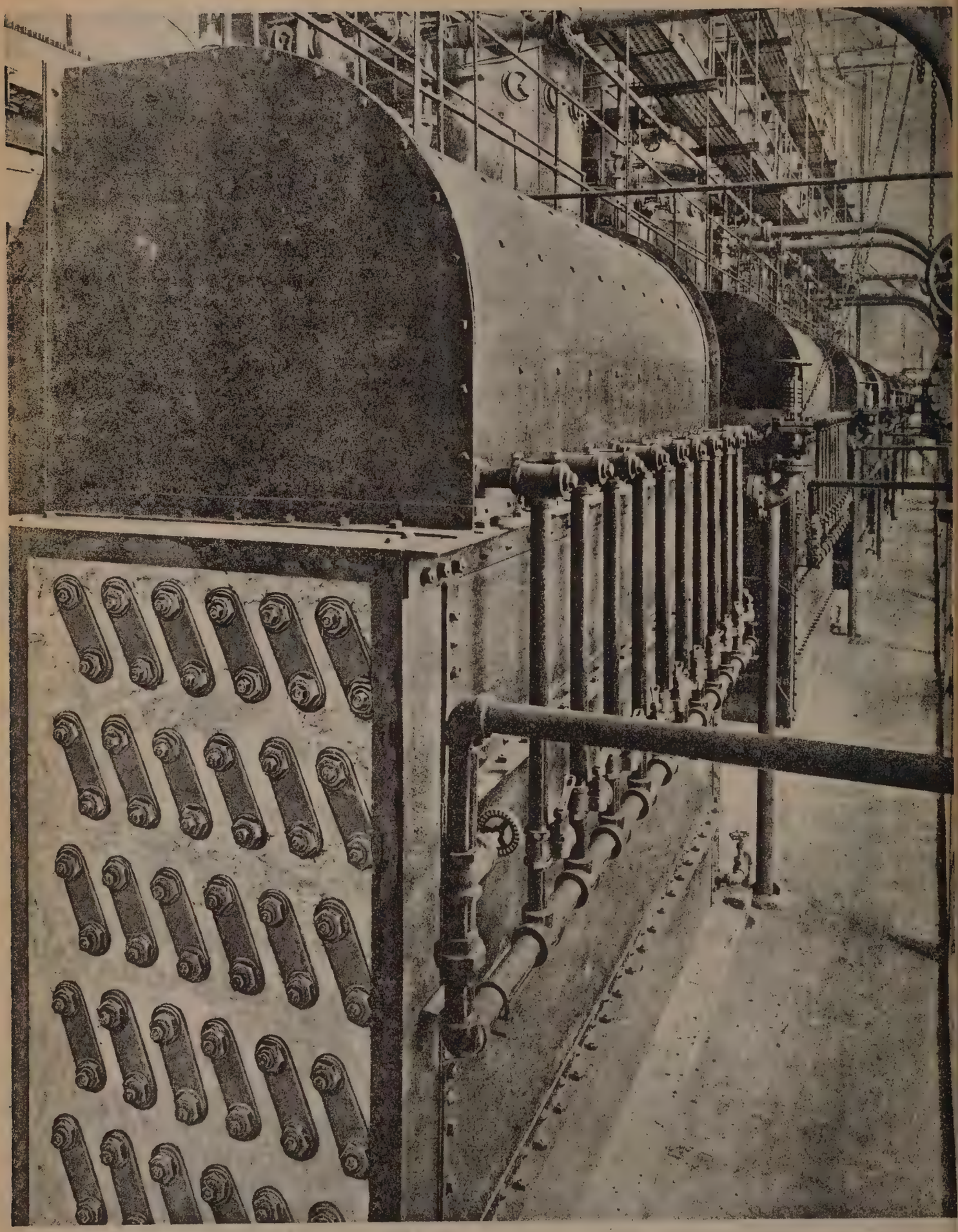
Side view of the Foster Economizer at the Delray plant of the Detroit Edison Company, showing the inlet flue, the end casing and the inlet and outlet water connections



Top view of the Foster Economizer at the Delray plant of the Detroit Edison Company, showing washing piping, the top casing and the relief valve connections

Economizer and that no dampers be installed between the boiler outlet and the economizer inlet. A large bypass flue is entirely unnecessary with the Foster Economizer. The heating surface is so rugged that the pressure parts will not be injured even if the gases pass through the economizer chamber while no water is in circulation. Also the casing is so arranged that all of the expanded joints may be inspected or re-rolled while the gases have unrestricted passage. It is, however, desirable in installations where high peak loads are encountered for short periods to provide a small spillway or bypass of proper dimensions to spill a portion of the excess gases developed during these peak points. This spillway should be protected by the labyrinth form of damper. This small overload spillway should, however, in no way be confused with the large bypass flues adopted with the older forms of economizer and designed to carry all of the gases around the economizer.

The overload spillways may be installed either within the economizer casing as illustrated on pages 20 and 26 or they may be built outside of and connected with the economizer flues as shown on page 19.



Six Foster Economizers at the plant of the Mac Sim Bar Paper Company, Otsego, Mich. Doors of firs Economizer opened to show return headers and end insulation.
Diagram of this installation is shown on page 23

Calculation of Fuel Saving

AN economizer may be considered as a feedwater heater or as a lue-gas cooler and the economy resulting from its use under any given load ondition may be readily estimated. t has been stated that the simplest alculation incident to power plant vork is figuring the saving due to an conomizer if the load is known.

If the apparatus is considered as a eedwater heater the saving is found y subtracting the heat above 32 deg. ahr. in the feed to the economizer from he total heat in the steam at the uperheater outlet and dividing this esult into the water rise shown by the conomizer, or

$$\text{Saving in per cent} = \frac{\text{Rise}}{H - h} \times 100$$

where H is the total heat in the steam and is the heat in the feed entering the economizer.

Under average conditions of pressure nd superheat, it will be found from the bove that the net saving due to an conomizer will be slightly less than per cent for each 10 deg. added to the vater.

If the economizer is considered as a gas cooler the saving may be found by subtracting the heat in the gases at the economizer outlet from the heat in the gases at the economizer inlet and lividing this by the total heat in the gases at the furnace, or

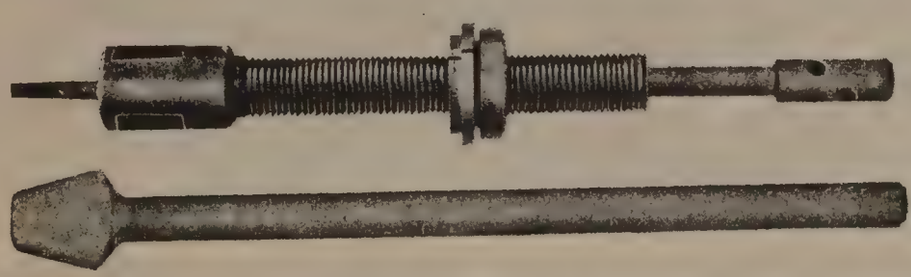
$$\text{Saving in per cent} = \frac{.24\ G\ (T_1 - T_2)}{E_1 \times \text{B.t.u. per lb. fuel as fired}}$$

where G is the weight of gas per lb. of fuel as fired, T_1 is the temperature of the gases entering the economizer, T_2 is the temperature of the gases leaving the economizer, and E_1 is the overall efficiency of the boiler and economizer.

Under average conditions of combustion and pressure the above calculation will show that approximately 1 per cent saving will result from each 35 deg. fahr. reduction in the flue gases.

While the saving to be obtained from an economizer installation under any given load condition may be readily found by the above methods the result may be misleading if the load is not accurately calculated. Care should be taken to estimate the quantity of steam to be demanded for each group of hours through the day and the number of days of such operation for the year. If the hourly and daily operation are approximately uniform an average may be easily estimated, but if high peak loads or regular periods of banking are to be encountered a summary should be made of these and the water rise for each rating taken and the annual saving then calculated from this series of results.

From the gross saving obtained as indicated, the cost of the induced draft should properly be deducted. If the fans are engine driven and the exhaust used in the feedwater heater, this will be a minimum, but if the proper plant heat balance is best obtained by motor-driven induced draft fans, the cost at the bus-bars of the current used by the motors should be deducted.



2-In. expander and belling tool for all expanded joints of the Foster Economizer

Increase of Boiler Capacity

WHILE the fuel saving, as noted in the foregoing pages, is usually the main inducement for installing economizers, the increased capacity of the boiler room, as obtained by their use, has solved several specific problems. Frequently additional steam may be required and space conditions are such as to preclude installing additional boilers, while ample space is available for economizers. In such instances the economizer performance is calculated on a basis of capacity rather than efficiency.

Steel housing and cast-iron lining of a two-pass Foster Economizer. Photo taken at the shops before installation of the heating elements

Calculation of Increased Capacity

THE increased capacity may be calculated from the formula:

$$\text{Increased capacity in per cent} = \frac{S}{R_2 - R_1}$$

where S = economizer surface per rated boiler horsepower and R_2 = rated capacity of the boiler only with the economizer and R_1 rated capacity of the boiler without the economizer.

For example, if a given boiler cannot be efficiently operated at more than 200 per cent of rating and it is found that it can be economically operated at 250 per cent in conjunction with a 60 per cent economizer and that such an economizer will do 12 per cent of the work of the combined unit at this rating, we find that a 60 per cent economizer will increase the maximum boiler capacity by 40 per cent.

From this it will be noted that under average combustion and pressure conditions one additional boiler horsepower may be obtained from each 7½ sq. ft. of economizer surface installed and this increased capacity will be obtained with much higher efficiency than before the economizer was installed.

Corrosion of Tubes

ANY heating surface may be corroded outside, inside or both.

External corrosion, which has been the more troublesome of the two, is caused by the sulphuric content in the fuel which, combined with the water of combustion, is deposited on the heating surface by the gases. External corrosion is completely prevented in the Foster Economizer partially because the gases of combustion come into contact only with cast iron, which is a superior material to resist this pitting action but primarily because the process of washing the entire economizer chamber admits sufficient water to completely carry away any sulphurous or sulphuric acids that may have been deposited on the tubes. Complete elimination of external corrosion troubles is a marked advantage of Foster construction and the method adopted for cleaning it.

Internal corrosion is caused by the non-condensable gases occluded in the water. Of these, nitrogen is entirely inactive and hydrogen is generally so. Oxygen however does produce corrosion. The oxygen content may be very easily and surely reduced by heating the incoming water to a temperature of from 180 to 210 deg. fahr. in an open heater. This heat can be added without a loss of plant economy, especially if the induced draft fans are steam driven and the exhaust conveyed to the heater. Further the Foster Economizer is designed for rapid water circulation and positive velocity through all the pressure parts, which is a decided preventive of any internal corrosive action.

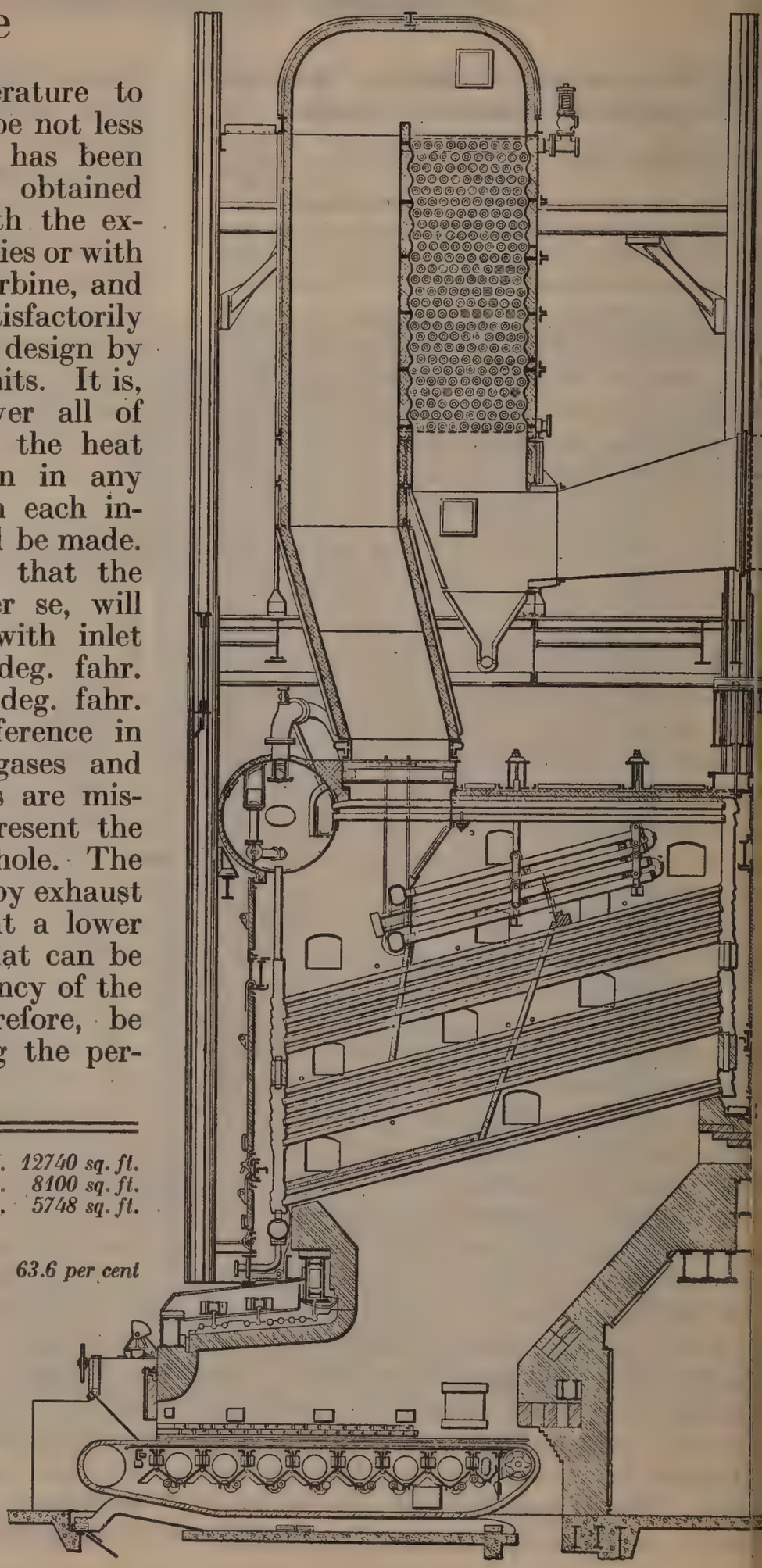
Much has been written about the damage of internal corrosion to steel-tube economizers and a few incidents are of record where corrosive action has damaged steel-tube economizers. In all of these cases, however, the circulation in the economizer was so slow that the oxygen was given full opportunity to attack the steel or the water was admitted to the economizer at a temperature so low that the oxygen had not been expelled. A user of the Foster Economizer may, however, have complete assurance that with the rapid circulation obtained in it, no trouble will be experienced from internal corrosion if the water is heated in an open heater to at least 180 deg. fahr.

Heat Balance

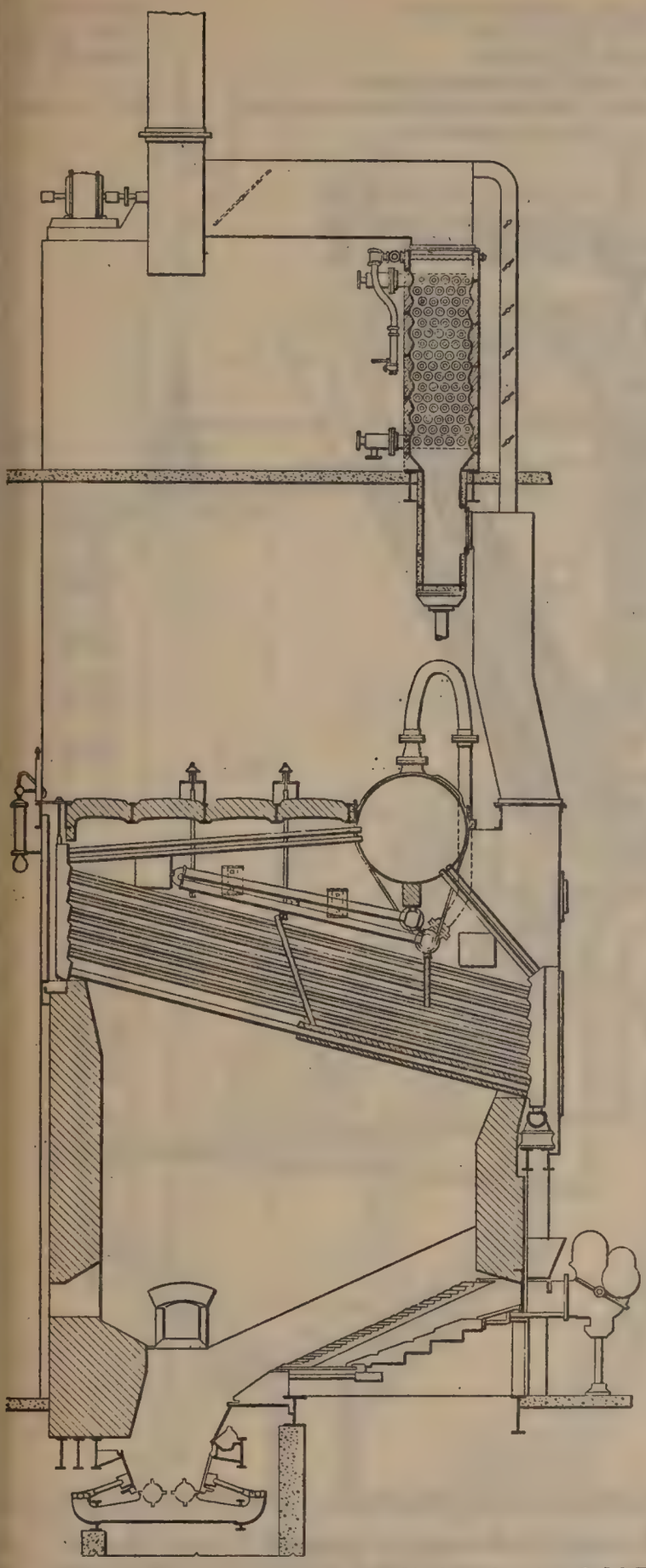
THE inlet water temperature to any economizer should be not less than 180 deg. fahr. This has been proven to be economically obtained in the majority of cases with the exhaust steam from the auxiliaries or with the exhaust from a house turbine, and it is also being most satisfactorily obtained in plants of recent design by bleeding the main turbine units. It is, however, impossible to cover all of the factors that enter into the heat balance of a power station in any brief general statement. In each instance careful analysis should be made.

While it may be argued that the economizer performance, per se, will show a greater efficiency with inlet water at from 60 to 130 deg. fahr. than at from 180 to 210 deg. fahr. because of the greater difference in temperature between the gases and the water, such calculations are misleading as they do not represent the efficiency of the plant as a whole. The heat added to the feedwater by exhaust steam should be obtained at a lower cost than any other heat that can be supplied. The overall efficiency of the power station should, therefore, be borne in mind in estimating the performance of an economizer.

Heating surface of Heine Boiler	*12740 sq. ft.*
Heating surface of Foster Economizer . .	*8100 sq. ft.*
Heating surface of Foster Superheater . .	*5748 sq. ft.*
Boilers equipped with chain-grate stokers.	
Ratio of economizer heating surface to boiler heating surface	*63.6 per cent*



Foster Economizers as applied to Heine Boilers at the plant of the Kansas City Light & Power Co., Kansas City, Mo. These economizers are the one-pass type in which the gases pass downward and the water is forced upward



Counter-Current Flow

ONE of the principal advantage of the Foster Economizer is tha it is always designed for complet counter-current flow. This is obtaine because the inlet header is placed a the end farthest from the hottest gase and the water is forced through a singl horizontal row of elements and bac through the next row and so forth unti it reaches the end that the gas enter where the last row of elements connec to the outlet header.

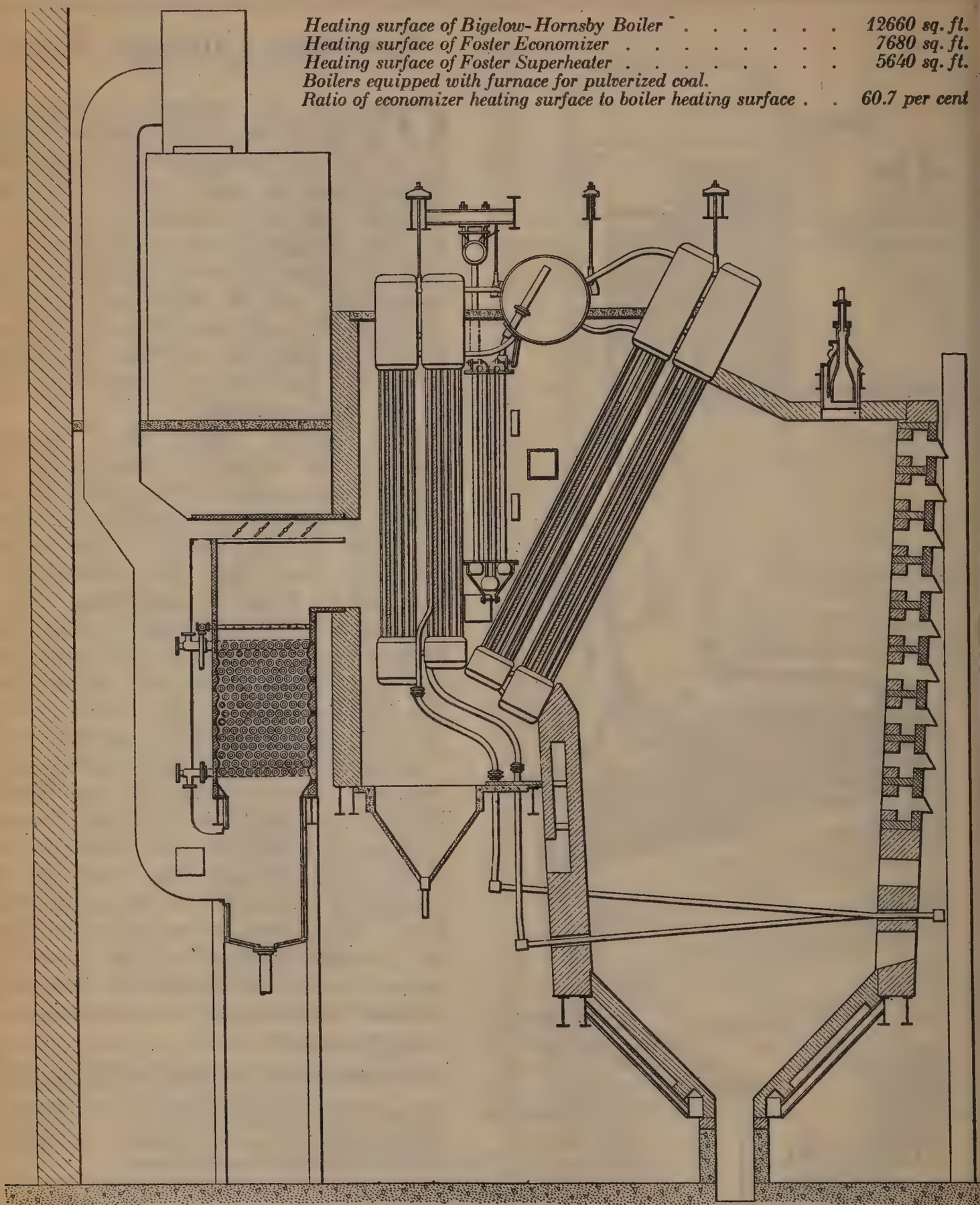
The hottest gases thus imping against the elements containing th hottest water and as the gases pass on row of elements after another the wate is cooler in each row. This featur decidedly increases the efficiency o any size or type of economizer and i the case of the larger sizes, permits th economical reduction of the gases fron the economizer outlet to a point belov the temperature of the water leavin the economizer and entering the boile

It should be especially noted that th velocity of the water in the Foste Economizer is sufficiently high to permi a downward flow of the water instea of the usual upward flow without an danger of re-circulation or water ham mer. This feature permits adoptin an upward passage of the gases, a shown by the illustration on this page without sacrificing the advantages o counter-current flow.

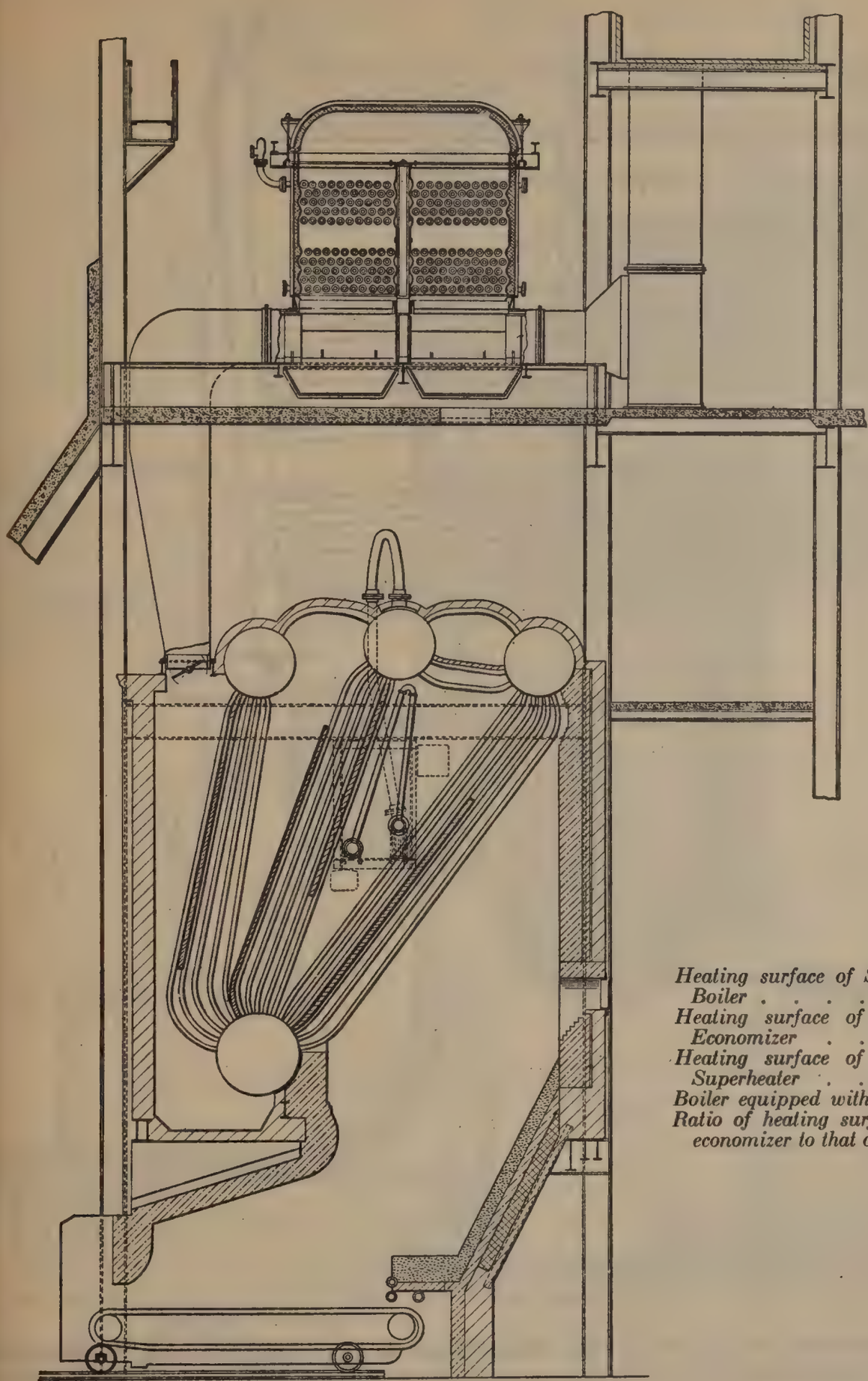
Heating surface of Springfield Boiler .	*4940 sq. f*
Heating surface of Foster Economizer. .	*2400 sq. f*
Heating surface of Foster Superheater .	*1331 sq. f*
Boilers equipped with underfeed stoker.	
Ratio of economizer heating surface to that of boiler	*48.6 per cer*

Foster Economizers as applied to Springfield Boilers at the plant of the Fort Dodge Gas & Electri Co., Fort Dodge, Iowa. The economizers are located above the boilers and are of the one-pass type wit gases passing upwards and water passing downward. The economizer flues are supplemented b small spillway bypasses of sufficient size to bypass the excess gases generated when operating at ove 250 per cent of rated capacity for short periods

Heating surface of Bigelow-Hornsby Boiler	*12660 sq. ft.*
Heating surface of Foster Economizer	*7680 sq. ft.*
Heating surface of Foster Superheater	*5640 sq. ft.*
Boilers equipped with furnace for pulverized coal.	
Ratio of economizer heating surface to boiler heating surface . .	*60.7 per cent*

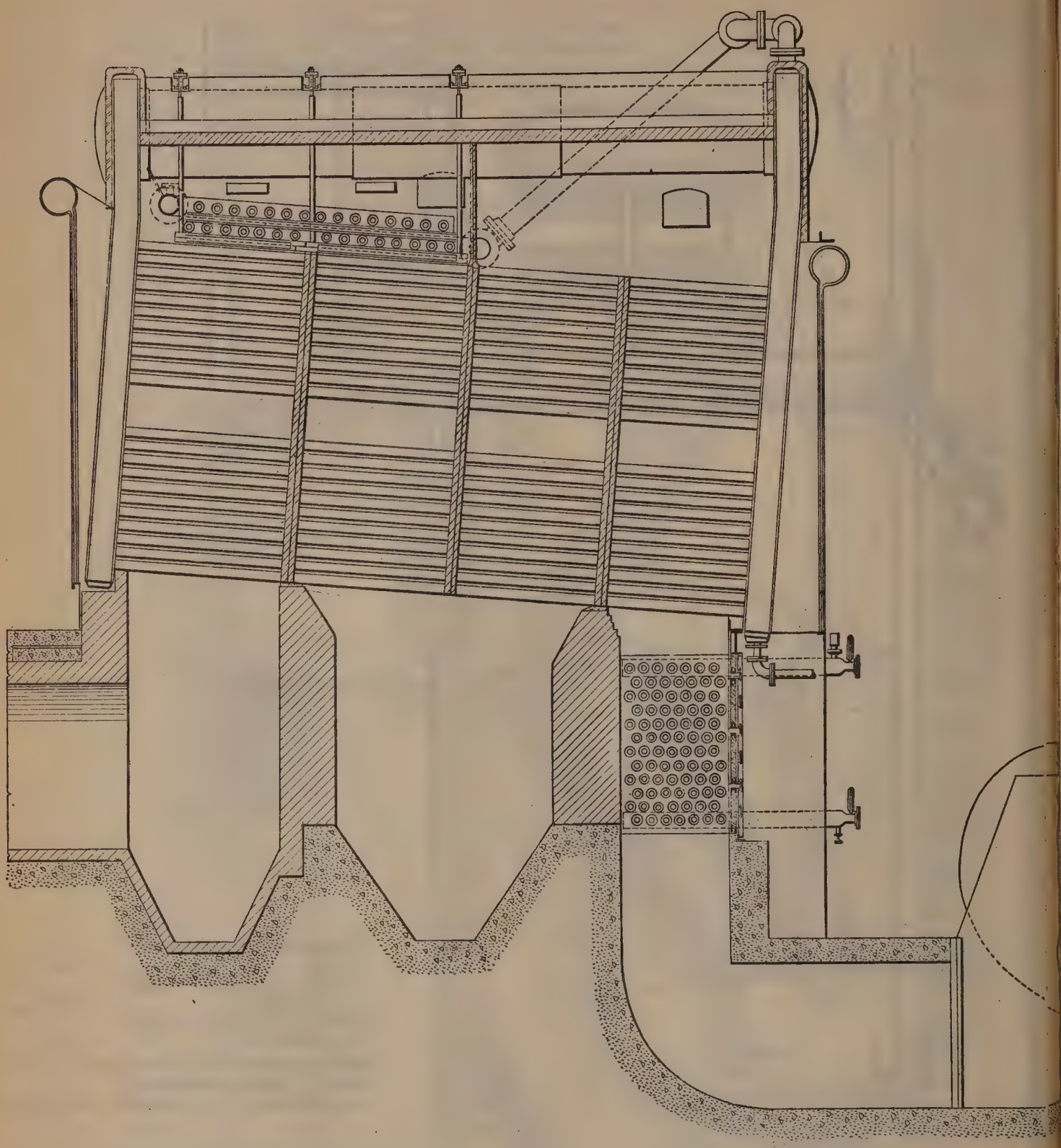


Foster Economizers as applied to Bigelow-Hornsby Boilers at the plant of United Electric Rai ways Company, Providence, R. I. The Economizers are located at the rear of the boilers, with flue arranged so as to clear the main boiler flue previously constructed, and are of the one-pass type wit gases passing downward and water forced upward. The economizer flues are supplemented by manually controlled spillway for bypassing the surplus gases when operating at over 300 per cer of rating for short periods



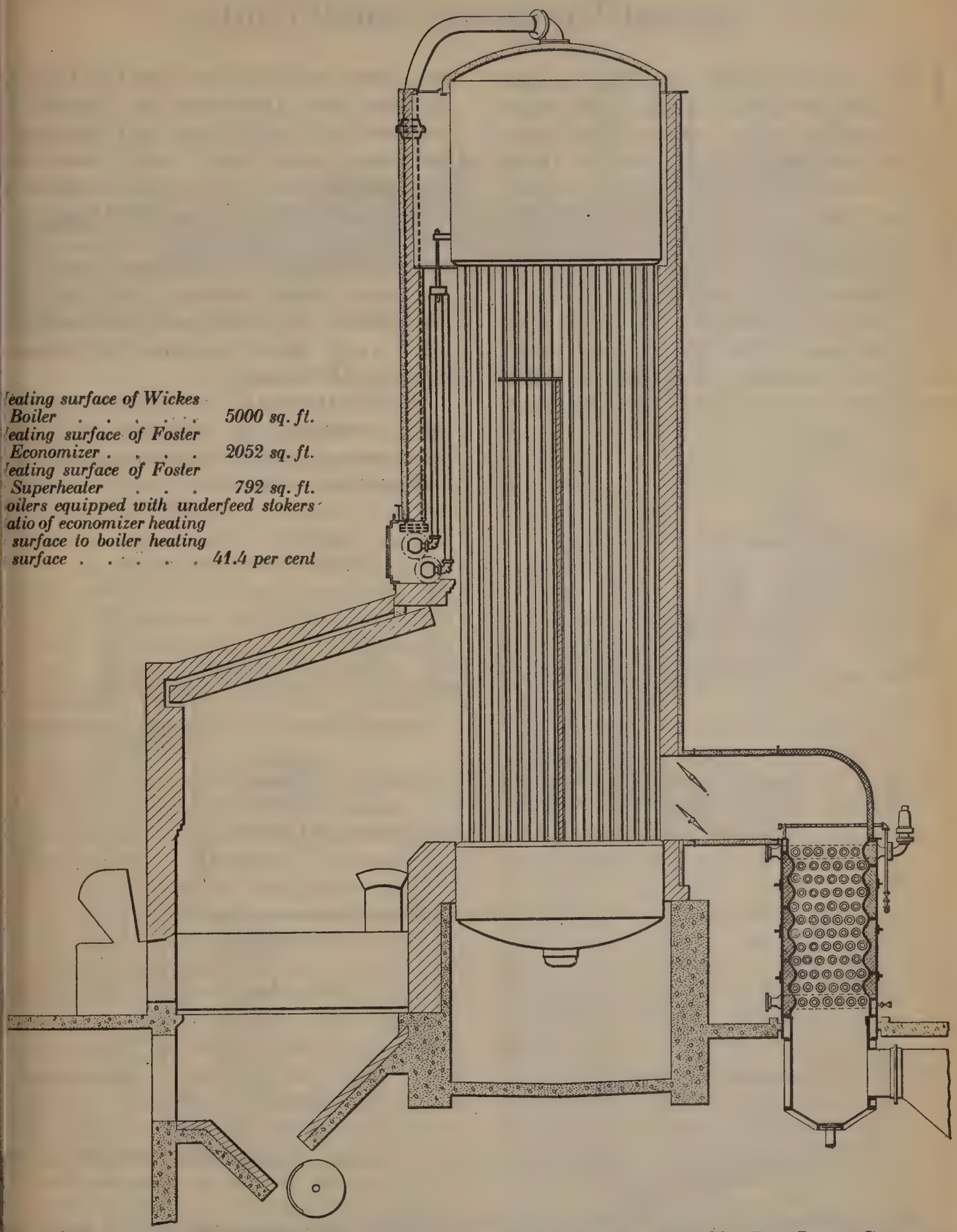
Heating surface of Stirling Boiler	*6865 sq. ft.*
Heating surface of Foster Economizer	*4800 sq. ft.*
Heating surface of Foster Superheater	*918 sq. ft.*
Boiler equipped with chain-grate stokers.	
Ratio of heating surface of economizer to that of boiler	*69.9 per cent*

Foster Economizer as applied to The Stirling Boiler at the plant of Cleveland Electric Illuminating ompany, Cleveland, Ohio. The economizer is located on a special floor above the boiler and is of the o-pass type. Details of the operation of the economizer are given on page 29



Heating surface of Edge Moor Boiler	*8826 sq. ft.*
Heating surface of Foster Economizer	*3141 sq. ft.*
Heating surface of Foster Superheater	*971 sq. ft.*
Boiler fired by waste heat from cement kiln.	
Ratio of heating surface of economizer to that of boiler	*35.6 per cent*

Foster Economizers as applied to Edge Moor Boilers at the plant of Cayuga Portland Cem Company, Portland Point, N. Y. The economizers are located in the boiler setting below the fou pass and are of the one-pass type, with gases passing downward and water forced upward. Due to nature of the fuel, these economizers are not washed with water, but are cleaned by steam lan applied through doors located at the rear of the settings



Heating surface of Wickes Boiler . . . . . 5000 sq. ft.
Heating surface of Foster Economizer . . . . 2052 sq. ft.
Heating surface of Foster Superheater . . . 792 sq. ft.
Boilers equipped with underfeed stokers
Ratio of economizer heating surface to boiler heating surface . . . . . 41.4 per cent

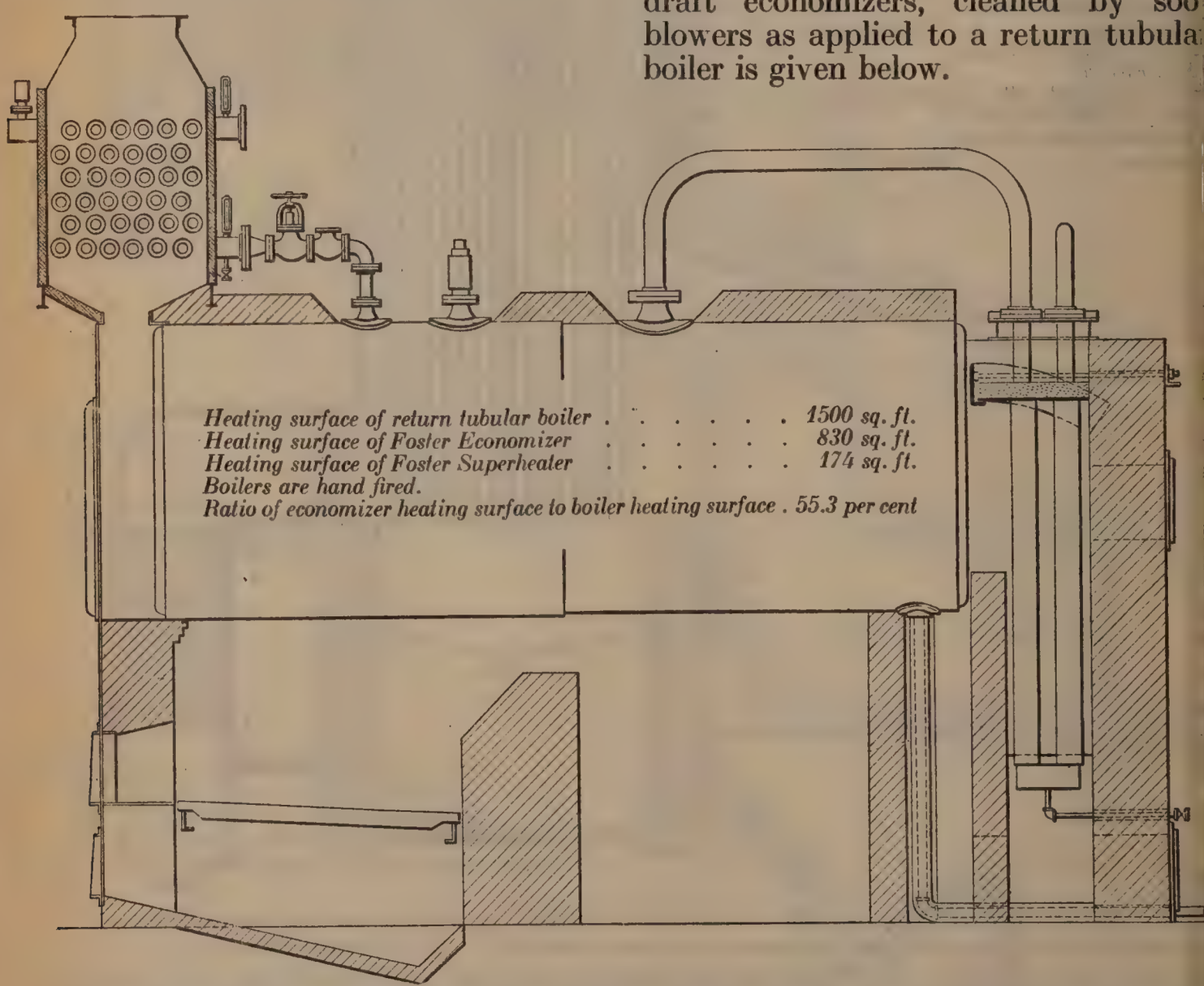
Foster Economizers as applied to Wickes Boilers at the plant of Mac Sim Bar Paper Company, Otsego, Mich. The economizers are located at the rear of the boilers and are of the one-pass type with gases passing downward and water forced upward. A photograph of this installation is shown on page 14

Special Design for Small Units

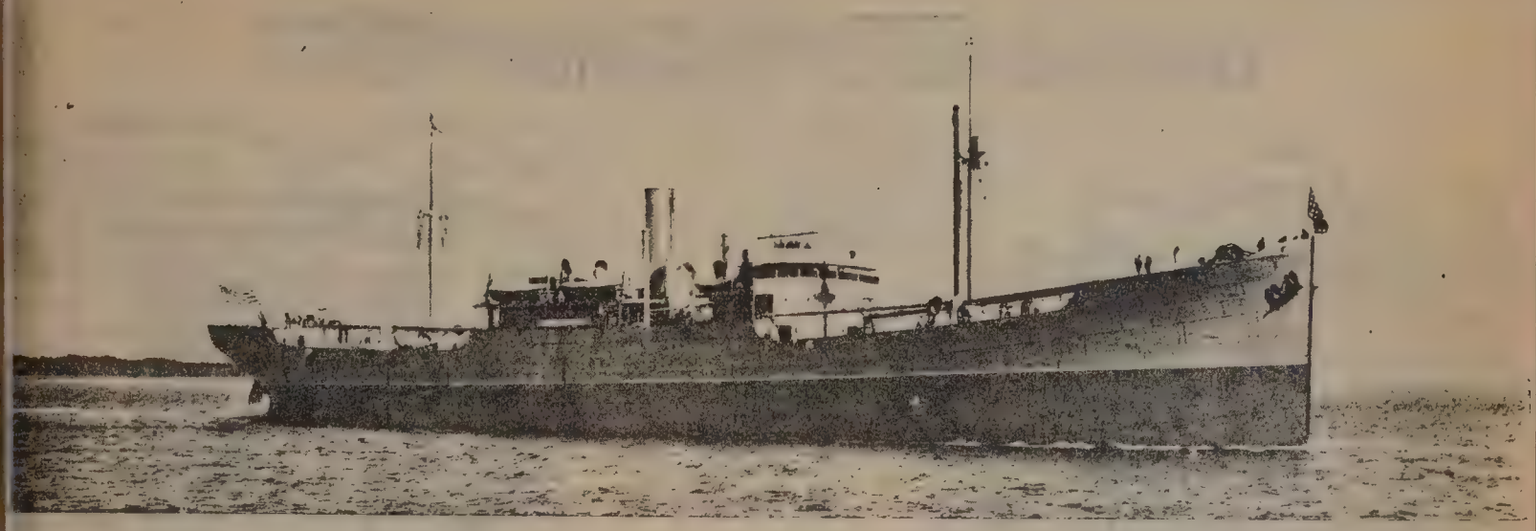
IN small economizer units the weight of the cast-iron housing is so great in proportion to the weight of the heating surface itself that the cost of these units is much greater for the work they do than that of the larger installations. In order to permit the operators of small boilers to benefit by the use of economizers at a reasonable initial cost, the Foster Economizer has been specially designed for these conditions. The small number of tubes in these units may be kept satisfactorily clean by steam soot blowers and the heating surface can, therefore, be housed in two sets of steel plates and the space between these filled with insulating material. The elements are supported by cast-iron end plates and these protected by steel doors.

These small economizers may be operated under natural draft and in old plants may frequently be installed with very slight expense for alterations in the flues.

An illustration of one of these natural draft economizers, cleaned by soot blowers as applied to a return tubular boiler is given below.



Foster Economizer as applied to a horizontal return tubular boiler at our own plant in Dansville N. Y. The Economizer is located immediately above the boiler outlet, and because of the small size and space available, is designed to be cleaned by a steam soot blower, instead of the usual washing device. Details as to the operation of an economizer similar to this are given on page 28



Economizers for Marine Service

THE extremely small bulk and the comparatively light weight of the Foster Economizer have led marine engineers to install it in several ships. While in general the changed conditions of recent years, including the higher cost of fuel, have initiated the marine economizer as they have popularized the economizer in stationary plants, the operations peculiar to steamships offer additional inducements for the use of the marine economizer.

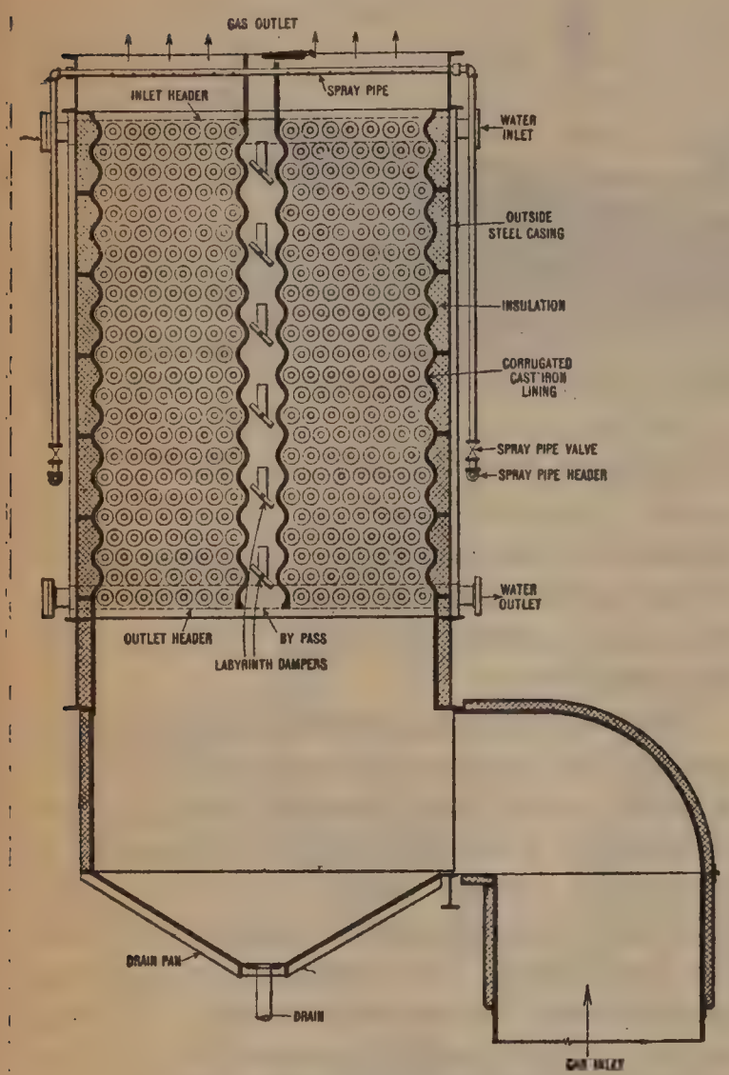
Marine boilers are usually operated at a higher rating than is customary on land and this results in high flue-gas temperatures. Formerly, when the Scotch marine boiler was almost exclusively used, these gases were reduced by an air heater through which the forced draft fans impelled the air supply for the furnace. The advent of the steam turbine in marine practice encouraged higher steam pressures and these were more readily obtained from water-tube boilers. This type of boiler has not been adapted to air heaters and the result was excessive stack losses.

Furthermore, many of the marine auxiliaries are now electrically driven and such as are still operated by steam are more efficient and it is now found that there is not sufficient exhaust steam on shipboard to heat the feedwater to the desired temperature except by using excessive back pressure on the auxiliaries.

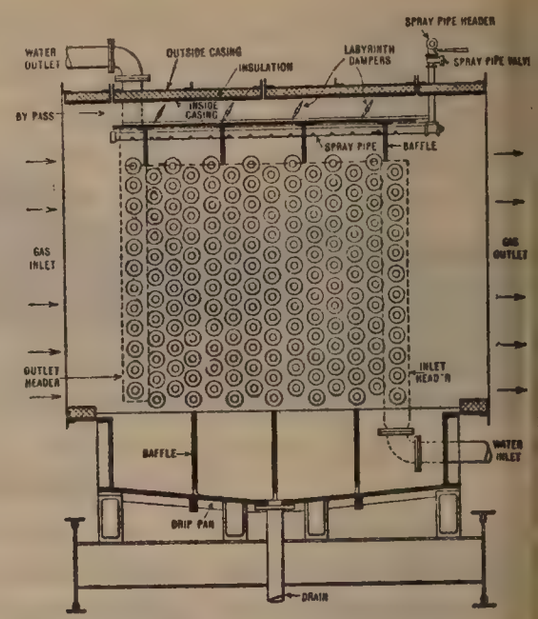
These two conditions naturally suggested the recovery of some of the heat wasted in the flue gases by heating the feedwater, and the marine economizer promptly found itself. As the condensate on shipboard is invariably used for boilerfeed, the marine circulating system may be entirely closed. Thus, as no oxygen will be entrained in the water fed to the economizer, the temperature at the economizer inlet may be as low as that at the condenser outlet without corrosive troubles.

The combination of a water-tube boiler, Foster Economizer and induced-draft fan occupies less space, has little if any more weight and gives higher overall efficiency than the less modern combination of a Scotch boiler, air heater and forced-draft fan, and the former can carry the higher pressures now demanded. Marine engineering is ultra conservative but this combination is recognized as the most important step that has been made in many years to safely improve the boiler room operation, and the installations now in operation prove the absolute reliability and improved economy of the new idea.

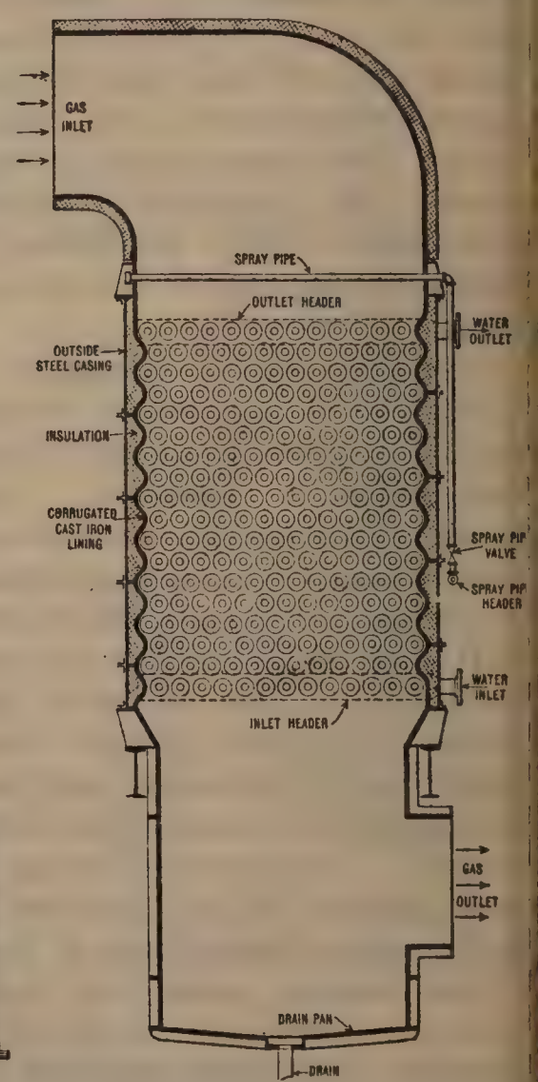
Arrangements of Economizer Surface



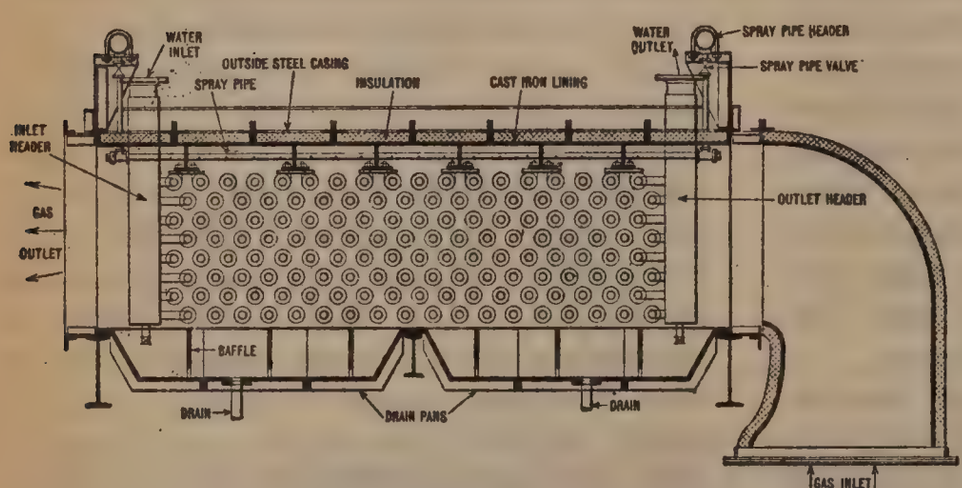
Vertical Pass of Gases
Gases up, water down, with spillway bypass in center of setting.



Horizontal Pass of Gases
with spillway bypass at top of setting

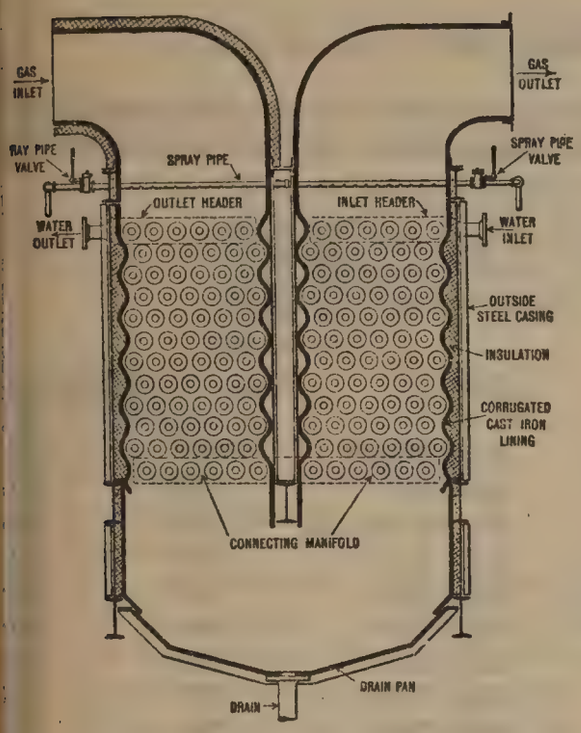


Vertical Pass of Gases
Gases down, water up.
No spillway.



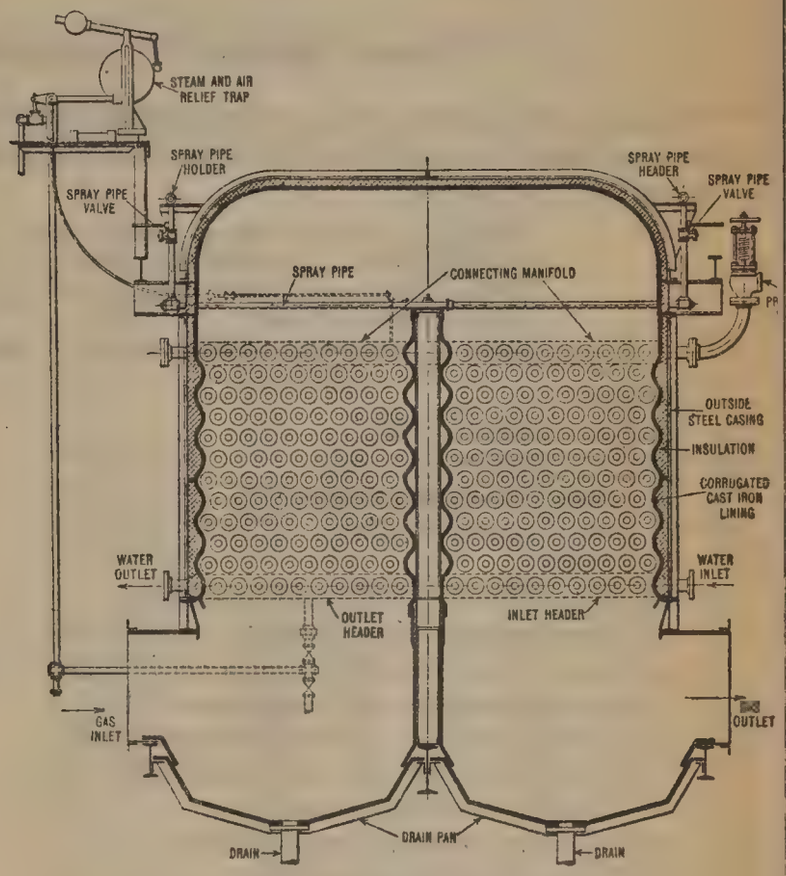
Horizontal Pass of Gases
Water passing horizontally in counter-current.
No spillway.

Arrangements of Economizer Surface



Two Vertical Passes

ll counter-current flow with gas inlet and outlet at top of housing.



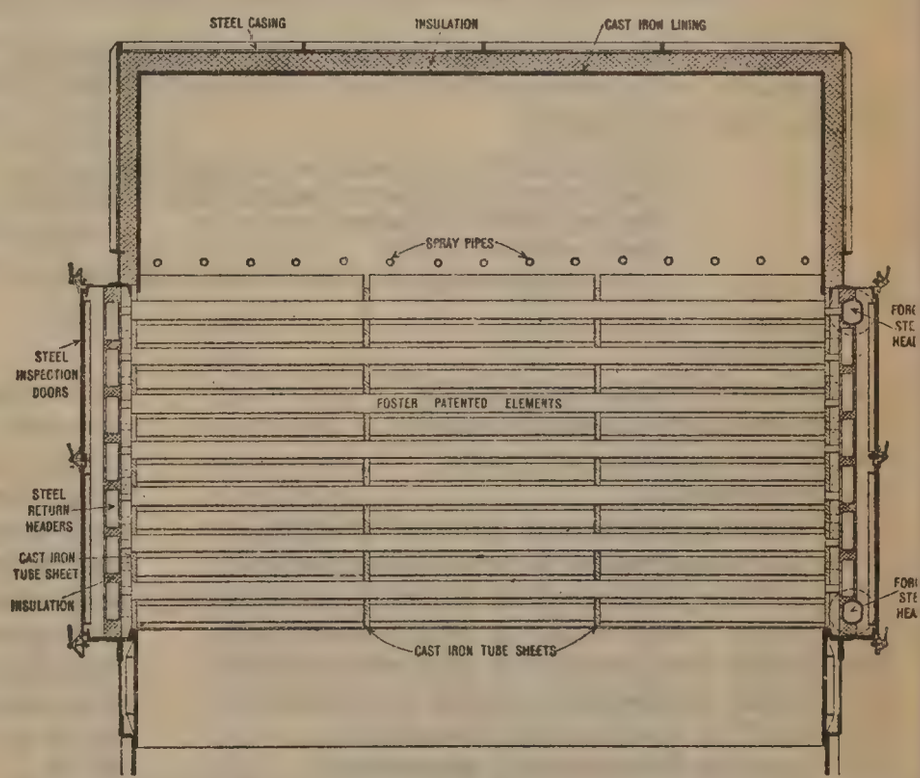
Two Vertical Passes

Full counter-current flow with gas inlet and outlet at bottom of housing.

HE arrangements of the Economizer Surface as ıown on these pages may be tered to suit conditions. /hen the gases are shown pass- ıg upward they may be passed ɔwnward provided the inlet ıd outlet water connections ·e reversed. Also spillway ypasses may be installed in omitted from all designs.

The longitudinal section of ıe horizontal gas-pass rangement is similar to that ıown in the cut except that ıe inlet and outlet manifolds ·e vertical instead of being ɔrizontal.

The inlet and outlet flue ɔnnections may also be tered and it is desirable to esign these so that the con- ɔction from the boiler outlet ıd to the fan inlet will be as ıort as possible.



Longitudinal section showing typical arrangement of a vertica pass economizer with details of pressure parts and housing.

Tests of Foster Economizers

Power Specialty Company, Dansville, N. Y.

Showing that at low ratings, the temperature of the outlet gases from a 55 per cent economizer with low draft loss, is over 100 deg. fahr. in excess of the temperature of the water from the economizer.

Heating surface of return-tubular boiler	1500 sq. ft.
Heating surface of Foster Superheater	174 sq. ft.
Heating surface of Foster Economizer	830 sq. ft.
Grate surface of boiler	41 sq. ft.
Ratio of economizer heating surface to that of boiler	55.3 per cent

1.	Date	1919	Mar. 23 to May 1	
2.	Number of tests run		8	5
3.	Power developed by unit	boiler hp.	157	19
4.	Percentage of rated capacity	per cent	105	13
5.	Steam pressure by gauge	lb. per sq. in.	110	10
6.	Superheat	deg. fahr.	134	14
7.	Gas temperature at economizer inlet	deg. fahr.	582	66
8.	Gas temperature at economizer outlet	deg. fahr.	404	42
9.	Gas temperature drop through economizer	deg. fahr.	178	24
10.	Water temperature at economizer inlet	deg. fahr.	200	19
11.	Water temperature at economizer outlet	deg. fahr.	283	30
12.	Water temperature rise in economizer	deg. fahr.	83	11
13.	Draft in flue leaving economizer	in. w. g.	.23	.3
14.	Draft in flue entering economizer	in. w. g.	.18	.2
15.	Draft loss through economizer	in. w. g.	.05	.1
16.	Fuel saving effected by economizer	per cent	7.58	10.

Riverside Station of Municipal Gas Co., Albany, N. Y.

Showing that at medium ratings, the temperature of the outlet gases from an 85 per cen economizer, with medium draft loss, is nearly 100 deg. lower than the temperature of the wate leaving the economizer.

Heating surface of special water-tube boiler	6877 sq. ft.
Heating surface of Foster Radiant Heat Superheater	65.2 sq. ft.
Heating surface of Foster Economizer	5856 sq. ft.
Grate surface of stoker	105 sq. ft.
Ratio of economizer heating surface to that of boiler	85.1 per cent

1.	Date	1921	July 27	Aug. 9	July 28	July 2
2.	Duration	hr.	6	6	6	6
3.	Power developed by unit	boiler hp.	805	935	1016	120
4.	Percentage of rated capacity	per cent	117	136	148	17
5.	Steam pressure by gauge	lb. per sq. in.	200	202	201	20
6.	Superheat	deg. fahr.	188	129	114	13
7.	Gas temperature at economizer inlet	deg. fahr.	582	663	646	69
8.	Gas temperature at economizer outlet	deg. fahr.	248	270	250	26
9.	Gas temperature drop through economizer	deg. fahr.	334	393	396	43
10.	Water temperature at economizer inlet	deg. fahr.	213	213	212	21
11.	Water temperature at economizer outlet	deg. fahr.	334	356	354	35
12.	Water temperature rise in economizer	deg. fahr.	121	143	142	14
13.	Draft in flue leaving economizer	in. w. g.	.50	1.20	1.20	1.5
14.	Draft in flue entering economizer	in. w. g.	+.05	−.07	+.01	−.1
15.	Draft loss through economizer	in. w. g.	.55	1.13	1.21	1.3
16.	Fuel saving effected by economizer	per cent	10.78	13.08	13.09	13.3

Tests of Foster Economizers—*Continued*

Cleveland Electric Illuminating Co., Cleveland, Ohio

Showing that over a wide range of loads, the temperature of the outlet gases from a 70 per cent economizer, with high draft loss, closely approaches the temperature of the outlet water.

Heating surface of Stirling Boiler	6865 sq. ft.
Heating surface of Foster Superheater	918 sq. ft.
Heating surface of Foster Economizer	4800 sq. ft.
Grate surface of chain grate stokers	177 sq. ft.
Ratio of economizer heating surface to that of boiler	69.9 per cent

1. Date	1921	Dec. 13	Dec. 14	Dec. 7	Dec. 6	Nov. 30	Dec. 9
2. Duration	hr.	12	12	12	12	10	10
3. Power developed by unit	boiler hp.	899	897	1434	1452	1890	1923
4. Percentage of rated capacity	per cent	131	131	209	212	275	280
5. Steam pressure by gauge	lb. per sq. in.	254	254	255	255	261	260
6. Superheat	deg. fahr.	146	140	130	132	134	138
7. Gas temperature at economizer inlet	deg. fahr.	520	543	568	568	617	624
8. Gas temperature at economizer outlet	deg. fahr.	268	254	280	287	310	315
9. Gas temperature drop through economizer	deg. fahr.	252	289	288	281	307	309
10. Water temperature at economizer inlet	deg. fahr.	166	162	174	170	166	164
11. Water temperature at economizer outlet	deg. fahr.	248	258	285	279	291	288
12. Water temperature rise in economizer	deg. fahr.	82	96	111	109	125	124
13. Draft in flue leaving economizer	in. w. g.	.88	.83	2.44	2.44	4.50	4.51
14. Draft in flue entering economizer	in. w. g.	.03	.04	.61	.57	1.37	1.33
15. Draft loss through economizer	in. w. g.	.85	.79	1.83	1.87	3.13	3.18
16. Fuel saving effected by economizer	per cent	7.14	8.37	9.83	9.63	11.00	10.86

Delray Station, Detroit Edison Co., Detroit, Mich.

Showing that at low ratings, the temperature of the outlet gases from a 52 per cent economizer with high draft loss approximates the temperature of the outlet water, but that at higher loads the gas temperature increases more rapidly than the water temperature.

Heating surface of Class W53 Stirling Boiler	23654 sq. ft.
Heating surface of Class W27 Stirling Boiler	12054 sq. ft.
Heating surface of B. & W. Superheater, large boiler	2217 sq. ft.
Heating surface of B. & W. Superheater, small boiler	1528 sq. ft.
Heating surface of Foster Economizer	18800 sq. ft.
Ratio of economizer heating surface to that of boilers	52.6 per cent

1. Date	1922	Apr. 20	Apr. 18	Apr. 19	Apr. 10	Apr. 17
2. Duration	hr.	2	3	3	3	3
3. Power developed by unit	boiler hp.	3859	5780	5867	6955	6978
4. Percentage of rated capacity	per cent	108	162	164	194	196
5. Steam pressure by gauge	lb. per sq. in.	210	212	212	213	215
6. Superheat	deg. fahr.	147	171	156	169	185
7. Gas temperature at economizer inlet	deg. fahr.	506	563	566	566	631
8. Gas temperature at economizer outlet	deg. fahr.	276	313	301	296	337
9. Gas temperature drop through economizer	deg. fahr.	230	250	265	270	294
10. Water temperature at economizer inlet	deg. fahr.	205	201	206	193	194
11. Water temperature at economizer outlet	deg. fahr.	272	273	283	282	296
12. Water temperature rise in economizer	deg. fahr.	67	72	77	89	102
13. Draft in flue leaving economizer	in. w. g.	2.18	3.66	4.16	5.35	5.31
14. Draft in flue entering economizer	in. w. g.	.60	.67	.82	.97	.81
15. Draft loss through economizer	in. w. g.	1.58	2.99	3.34	4.38	4.50
16. Fuel saving effected by economizer	per cent	6.03	6.39	6.90	7.85	8.93

Properties of Steam

t.—Temp. in deg. fahr. v.—Specific vol. in cu. ft. per lb. h.—Total heat in B.t.u. per lb. from water at 32 deg. fahr

Pressure in pounds per sq. in.			Water	Saturated steam	Degrees of superheat					
Absol.	Gauge				50°	100°	150°	200°	250°	300°
15	0.3	t.	213.0	213.0	263.0	313.0	363.0	413.0	463.0	513.0
		v.	0.02	26.27	28.40	30.46	32.50	34.53	36.56	38.58
		h.	181.0	1,150.7	1,174.2	1,197.6	1,221.0	1,244.4	1,267.7	1,291.1
40	25.3	t.	267.3	267.3	317.3	367.3	417.3	467.3	517.3	567.3
		v.	0.02	10.49	11.33	12.13	12.93	13.70	14.48	15.25
		h.	236.0	1,169.4	1,194.0	1,218.4	1,242.4	1,266.4	1,290.3	1,314.1
60	45.3	t.	292.7	292.7	342.7	392.7	442.7	492.7	542.7	592.7
		v.	0.02	7.17	7.75	8.30	8.84	9.36	9.89	10.41
		h.	262.1	1,177.0	1,202.6	1,227.6	1,252.1	1,276.4	1,300.4	1,324.3
80	65.3	t.	312.0	312.0	362.0	412.0	462.0	512.0	562.0	612.0
		v.	0.02	5.47	5.92	6.34	6.75	7.17	7.56	7.95
		h.	282.0	1,182.3	1,208.8	1,234.3	1,259.0	1,283.6	1,307.8	1,331.9
100	85.3	t.	327.8	327.8	377.8	427.8	477.8	527.8	577.8	627.8
		v.	0.02	4.43	4.79	5.14	5.47	5.80	6.12	6.44
		h.	298.3	1,186.3	1,213.8	1,239.7	1,264.7	1,289.4	1,313.6	1,337.8
110	95.3	t.	334.8	334.8	384.8	434.8	484.8	534.8	584.8	634.8
		v.	0.02	4.05	4.38	4.70	5.01	5.31	5.61	5.90
		h.	305.5	1,188.0	1,215.9	1,242.0	1,267.1	1,291.9	1,316.2	1,340.4
120	105.3	t.	341.3	341.3	391.3	441.3	491.3	541.3	591.3	641.3
		v.	0.02	3.73	4.04	4.33	4.62	4.89	5.17	5.44
		h.	312.3	1,189.6	1,217.9	1,244.1	1,269.3	1,294.1	1,318.4	1,342.7
130	115.3	t.	347.4	347.4	397.4	447.4	497.4	547.4	597.4	647.4
		v.	0.02	3.45	3.74	4.02	4.28	4.54	4.80	5.05
		h.	318.6	1,191.0	1,219.7	1,246.1	1,271.4	1,296.2	1,320.6	1,344.9
140	125.3	t.	353.1	353.1	403.1	453.1	503.1	553.1	603.1	653.1
		v.	0.02	3.22	3.49	3.75	4.00	4.24	4.48	4.71
		h.	324.6	1,192.2	1,221.4	1,248.0	1,273.3	1,298.2	1,322.6	1,346.9
150	135.3	t.	358.5	358.5	408.5	458.5	508.5	558.5	608.5	658.5
		v.	0.02	3.01	3.27	3.51	3.75	3.97	4.19	4.41
		h.	330.2	1,193.4	1,223.0	1,249.6	1,275.1	1,300.0	1,324.5	1,348.8
160	145.3	t.	363.6	363.6	413.6	463.6	513.6	563.6	613.6	663.6
		v.	0.02	2.83	3.07	3.30	3.53	3.74	3.95	4.15
		h.	335.6	1,194.5	1,224.5	1,251.3	1,276.8	1,301.7	1,326.2	1,350.6
170	155.3	t.	368.5	368.5	418.5	468.5	518.5	568.5	618.5	668.5
		v.	0.02	2.68	2.91	3.12	3.34	3.54	3.73	3.92
		h.	340.7	1,195.4	1,225.9	1,252.8	1,278.4	1,303.3	1,327.9	1,352.3
180	165.3	t.	373.1	373.1	423.1	473.1	523.1	573.1	623.1	673.1
		v.	0.02	2.53	2.75	2.96	3.16	3.35	3.54	3.72
		h.	345.6	1,196.4	1,227.2	1,254.3	1,279.9	1,304.8	1,329.5	1,353.9
190	175.3	t.	377.6	377.6	427.6	477.6	527.6	577.6	627.6	677.6
		v.	0.02	2.41	2.62	2.81	3.00	3.19	3.37	3.55
		h.	350.4	1,197.3	1,228.6	1,255.7	1,281.3	1,306.3	1,330.9	1,355.5
200	185.3	t.	381.9	381.9	431.9	481.9	531.9	581.9	631.9	681.9
		v.	0.02	2.29	2.49	2.68	2.86	3.04	3.21	3.38
		h.	354.9	1,198.1	1,229.8	1,257.1	1,282.6	1,307.7	1,332.4	1,357.0
210	195.3	t.	386.0	386.0	436.0	486.0	536.0	586.0	636.0	686.0
		v.	0.02	2.19	2.38	2.56	2.74	2.91	3.07	3.23
		h.	359.2	1,198.8	1,231.0	1,258.4	1,284.0	1,309.0	1,333.7	1,358.4
220	205.3	t.	389.9	389.9	439.9	489.9	539.9	589.9	639.9	689.9
		v.	0.02	2.09	2.28	2.45	2.62	2.78	2.94	3.10
		h.	363.4	1,199.6	1,232.2	1,259.6	1,285.2	1,310.3	1,335.1	1,359.8
230	215.3	t.	393.8	393.8	443.8	493.8	543.8	593.8	643.8	693.8
		v.	0.02	2.00	2.18	2.35	2.51	2.67	2.82	2.97
		h.	367.5	1,200.2	1,233.2	1,260.7	1,286.5	1,311.6	1,336.3	1,361.0
240	225.3	t.	397.4	397.4	447.4	497.4	547.4	597.4	647.4	697.4
		v.	0.02	1.92	2.09	2.26	2.42	2.57	2.71	2.85
		h.	371.4	1,200.9	1,234.3	1,261.9	1,287.6	1,312.8	1,337.6	1,362.3
250	235.3	t.	401.0	401.0	451.0	501.0	551.0	601.0	651.0	701.0
		v.	0.02	1.85	2.02	2.17	2.33	2.47	2.61	2.75
		h.	375.2	1,201.5	1,235.4	1,263.0	1,288.8	1,313.9	1,338.8	1,363.5

Properties of Steam—*Continued*

(Marks & Davis, by permission of Longmans, Green & Co.)

Pressure in pounds per sq. in.			Water	Saturated steam	Degrees of superheat					
Absol.	Gauge				50°	100°	150°	200°	250°	300°
260	245.3	t.	404.5	404.5	454.5	504.5	554.5	604.5	654.5	704.5
		v.	0.02	1.78	1.94	2.10	2.24	2.39	2.52	2.65
		h.	378.9	1,202.1	1,236.4	1,264.1	1,289.9	1,315.1	1,340.0	1,364.7
270	255.3	t.	407.9	407.9	457.9	507.9	557.9	607.9	657.9	707.9
		v.	0.02	1.72	1.87	2.02	2.16	2.30	2.43	2.56
		h.	382.5	1,202.6	1,237.4	1,265.2	1,290.9	1,316.2	1,341.1	1,365.9
280	265.3	t.	411.2	411.2	461.2	511.2	561.2	611.2	661.2	711.2
		v.	0.02	1.66	1.81	1.95	2.09	2.22	2.35	2.48
		h.	386.0	1,203.1	1,238.4	1,266.2	1,291.9	1,317.2	1,342.2	1,367.0
290	275.3	t.	414.4	414.4	464.4	514.4	564.4	614.4	664.4	714.4
		v.	0.02	1.60	1.75	1.89	2.02	2.15	2.28	2.40
		h.	389.4	1,203.6	1,239.3	1,267.1	1,293.0	1,318.3	1,343.2	1,368.0
300	285.3	t.	417.5	417.5	467.5	517.5	567.5	617.5	667.5	717.5
		v.	0.02	1.55	1.69	1.83	1.96	2.09	2.21	2.33
		h.	392.7	1,204.1	1,240.3	1,268.2	1,294.0	1,319.3	1,344.3	1,369.2
310	295.3	t.	420.5	420.5	470.5	520.5	570.5	620.5	670.5	720.5
		v.	0.02	1.50	1.64	1.78	1.90	2.02	2.14	2.26
		h.	395.9	1,204.5	1,241.1	1,269.1	1,294.9	1,320.3	1,345.3	1,370.2
320	305.3	t.	423.4	423.4	473.4	523.4	573.4	623.4	673.4	723.4
		v.	0.02	1.46	1.59	1.72	1.85	1.96	2.08	2.19
		h.	399.1	1,204.9	1,242.0	1,270.0	1,295.9	1,321.3	1,346.3	1,371.3
330	315.3	t.	426.3	426.3	476.3	526.3	576.3	626.3	676.3	726.3
		v.	0.02	1.41	1.54	1.67	1.80	1.91	2.02	2.13
		h.	402.2	1,205.3	1,242.9	1,270.9	1,296.8	1,322.2	1,347.3	1,372.3
340	325.3	t.	429.1	429.1	479.1	529.1	579.1	629.1	679.1	729.1
		v.	0.02	1.37	1.50	1.63	1.75	1.86	1.97	2.08
		h.	405.3	1,205.7	1,243.8	1,271.8	1,297.8	1,323.2	1,348.3	1,373.3
350	335.3	t.	431.9	431.9	481.9	531.9	581.9	631.9	681.9	731.9
		v.	0.02	1.33	1.46	1.58	1.70	1.81	1.92	2.02
		h.	408.3	1,206.1	1,244.6	1,272.7	1,298.7	1,324.1	1,349.3	1,374.3
360	345.3	t.	434.6	434.6	484.6	534.6	584.6	634.6	684.6	734.6
		v.	0.02	1.30	1.42	1.54	1.65	1.76	1.87	1.97
		h.	411.2	1,206.4	1,245.4	1,273.6	1,299.6	1,325.0	1,350.2	1,375.3
370	355.3	t.	437.2	437.2	487.2	537.2	587.2	637.2	687.2	737.2
		v.	0.02	1.26	1.38	1.50	1.61	1.72	1.82	1.92
		h.	414.0	1,206.8	1,246.2	1,274.4	1,300.4	1,325.9	1,351.1	1,376.2
380	365.3	t.	439.8	439.8	489.8	539.8	589.8	639.8	689.8	739.8
		v.	0.02	1.23	1.35	1.47	1.58	1.68	1.78	1.88
		h.	416.8	1,207.1	1,247.0	1,275.3	1,301.3	1,326.8	1,352.0	1,377.1
390	375.3	t.	442.3	442.3	492.3	542.3	592.3	642.3	692.3	742.3
		v.	0.02	1.20	1.32	1.43	1.54	1.64	1.74	1.83
		h.	419.5	1,207.4	1,247.8	1,276.1	1,302.2	1,327.7	1,353.0	1,378.1
400	385.3	t.	444.7	444.7	494.7	544.7	594.7	644.7	694.7	744.7
		v.	0.02	1.17	1.28	1.40	1.50	1.60	1.70	1.79
		h.	422.2	1,207.7	1,248.6	1,276.9	1,303.0	1,328.6	1,353.9	1,379.1
450	435.3	t.	456.5	456.5	506.5	556.5	606.5	656.5	706.5	756.5
		v.	0.02	1.04	1.14	1.25	1.35	1.44	1.53	1.61
		h.	435.0	1,209.0	1,252.0	1,281.0	1,307.0	1,333.0	1,358.0	1,383.0
500	485.3	t.	467.2	467.2	517.2	567.2	617.2	667.2	717.2	767.2
		v.	0.02	0.93	1.03	1.13	1.22	1.31	1.39	1.47
		h.	448.0	1.210.0	1,256.0	1,285.0	1,311.0	1,337.0	1.362.0	1,388.0
550	535.3	t.	477.2	477.2	527.2	577.2	627.2	677.2	727.2	777.2
		v.	0.02	0.85	0.94	1.03	1.11	1.20	1.27	1.34
		h.	458.0	1,210.0	1,260.0	1,288.0	1,315.0	1,341.0	1,366.0	1,392.0
600	585.3	t.	486.4	486.4	536.4	586.4	636.4	686.4	736.4	786.4
		v.	0.02	0.78	0.86	0.95	1.03	1.11	1.18	1.25
		h.	469.0	1,211.0	1,264.0	1,293.0	1,319.0	1,346.0	1,371.0	1,397.0

Data Required for Economizer Proposal

AS has been explained in the previous pages no general rules can be followed to determine the size, arrangement and operating conditions best adapted for any prospective economizer installation. To intelligently establish these each case must be considered as a separate problem and calculations made from the following data:

1. ***Fuel*** (a) Ultimate or proximate analysis, (b) method of firing and (c) cost per ton (or bbl.) in the furnace.

2. ***Gases Leaving Boiler*** (a) Temperature and (b) percent of excess air or CO_2 at ratings as given in (*4*).

3. ***Boilers*** (a) Number, size and type, (b) steam pressure, superheat and feed temperature and (c) efficiency without economizer at ratings as given in (*4*).

4. ***Load*** (a) Minimum, (b) average or normal and (c) maximum lb. of steam per hr. to be generated and (d) number of hours per year of each.

5. ***Induced Draft*** (a) Drive preferred, if (b) motor, the current available and if (c) engine or turbine, the uses for exhaust steam.

6. ***Drawings*** (a) Plan and elevation of boiler room, showing boiler settings, flues, breechings and chimneys (b) all to give the space available for the economizer.

Standard Equipment

THE equipment regularly furnished with the Foster Economizer embraces: (a) the heating surface complete from inlet to outlet flanges inclusive; (b) the housing, consisting of the cast-iron side and end plates, the insulating material, sheet-steel plates and doors and the cast-iron pans all complete and arranged for the inlet and outlet flue connections; (c) the piping for washing and the valves for same; (d) the pressure-relief valve and (e) the inlet and outlet thermometers.

The above forms the entire economizer unit exclusive of the structural steel supports, the flue connections, the induced draft fans and fan drive and the water connections. However, if desired, all co-rolated equipment can be supplied with the actual economizer.

It is recommended that the erection of all Foster Economizers be superintended by a mechanic skilled in this work.

A. EUGENE MICHEL
ADVERTISING ENGINEER
116 NASSAU STREET NEW YORK

SUPERHEATED STEAM

FOSTER SUPERHEATERS

FOSTER EXTENDED SURFACE

THE FOSTER SUPERHEATER

for stationary water-tube and fire-tube boilers

BULLETIN
No. 303

POWER SPECIALTY COMPANY

ESTABLISHED 1898 - INCORPORATED 1900

Foster Superheaters for stationary and marine boilers and locomotives
Foster Economizers—Water Walls—Oil Heaters
Special heating and superheating apparatus for industrial processes

GENERAL OFFICES: 111 BROADWAY, NEW YORK

BOSTON DETROIT CHICAGO KANSAS CITY DALLAS DENVER
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PITTSBURGH GREAT BRITAIN: Power Specialty Company, Ltd. LOS ANGELES
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Works: Egham, England

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FOSTER SUPERHEATERS are the recognized standard for producing superheat with resulting steam and fuel savings and power increase without the employment of additional boiler units. Further benefits from the use of these Superheaters are explained on following pages.

Installations in over 5,000,000 hp. of boilers are daily making very substantial savings for their owners. In many instances economical operation would be quite impossible without the superheaters.

Our assurances of improved service are based upon abundant records from highly profitable installations, and our business policy demands that the mere making of sales be subordinated to giving the customer fair play and long-time satisfaction.

The 25-year experience of our engineers is always at the disposal of present and prospective customers. If you desire advice, performance data or estimates of cost and savings, read the last page of this booklet and write to our nearest office.

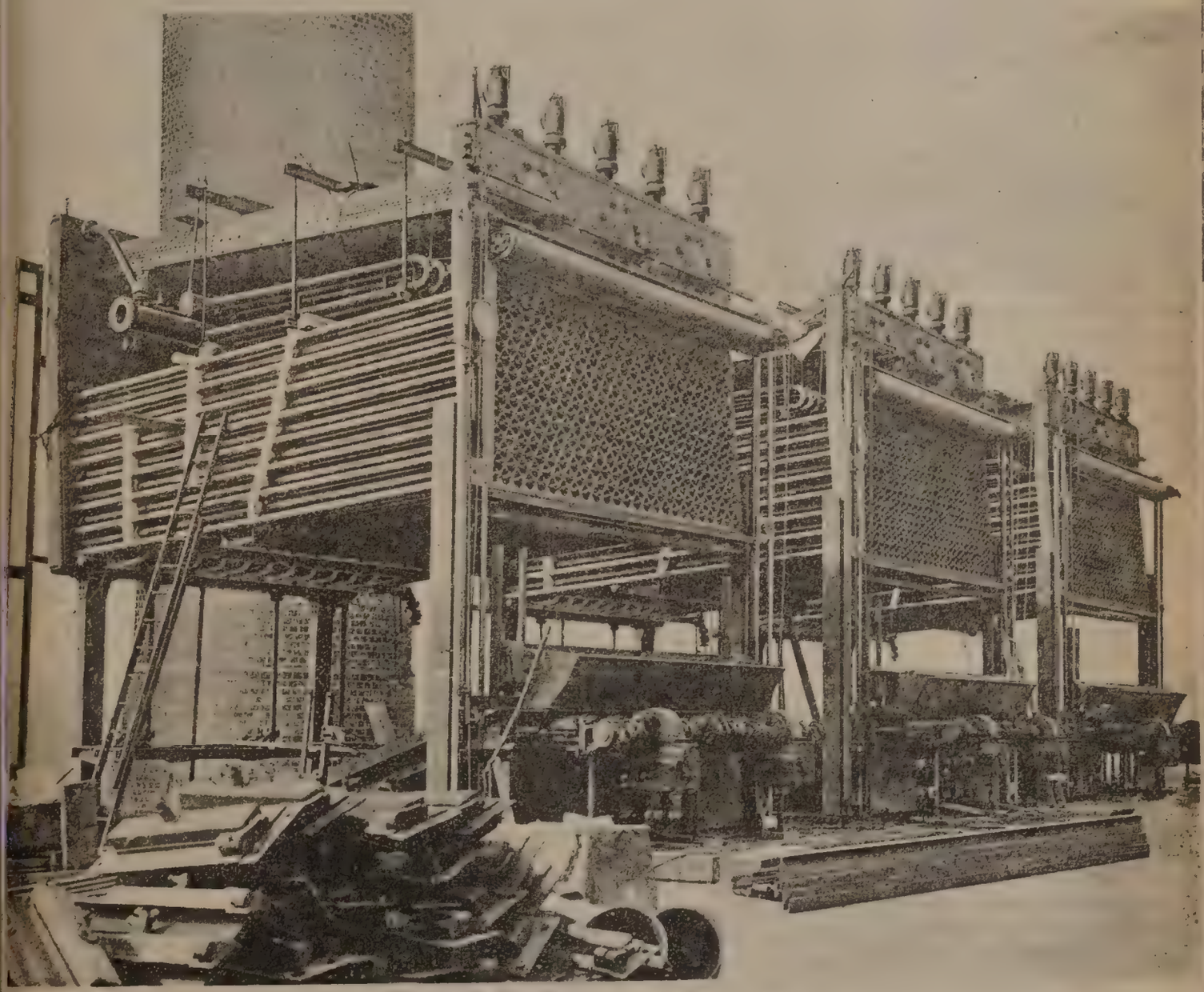
POWER SPECIALTY COMPANY

Advantages of Using Superheated Steam

THE value of superheated steam as a means of saving fuel in power plants and also for obtaining high steam temperatures regardessure is now generally recognized, and obtaine of superheaters has become almost uniersal in the modern power station.

Steam when first formed in the boiler has the same temperature as the water from which it is generated and contains a small percentage of finely divided mechanically suspended particles of water. In this condition it is commonly alled saturated steam. If this saturated steam oe separated from the main body of water from which it is produced and exposed to further heating, it is dried out, becomes entirely gaseous, absorbs additional heat, and is known as superheated steam. In this condition its temperature can be raised to any desired degree at any desired pressure, its volume increasing at the same time. In this latter respect superheated steam follows the law of perfect gases, increasing in volume in direct proportion to the absolute temperature.

Superheated steam has the advantage of remaining dry and gaseous as long as any of the superheat remains. The heat radiated from the piping system thus simply reduces the degree of superheat and does not cause the steam to break down into water as would occur with saturated steam. Even a moderate degree of



Foster Superheaters in three 813-hp. Edge Moor Boilers at the plant of the Viscose Co., Lewistown, Pa. The construction differs from the usual in vertically baffled longitudinal drum water-tube boilers only in that the pipe connections from boiler to superheater consist of a number of pipe bends leading from the steam space at the top of the rear boiler header to the superheater inlet header, the number of bends depending upon the size of the boiler

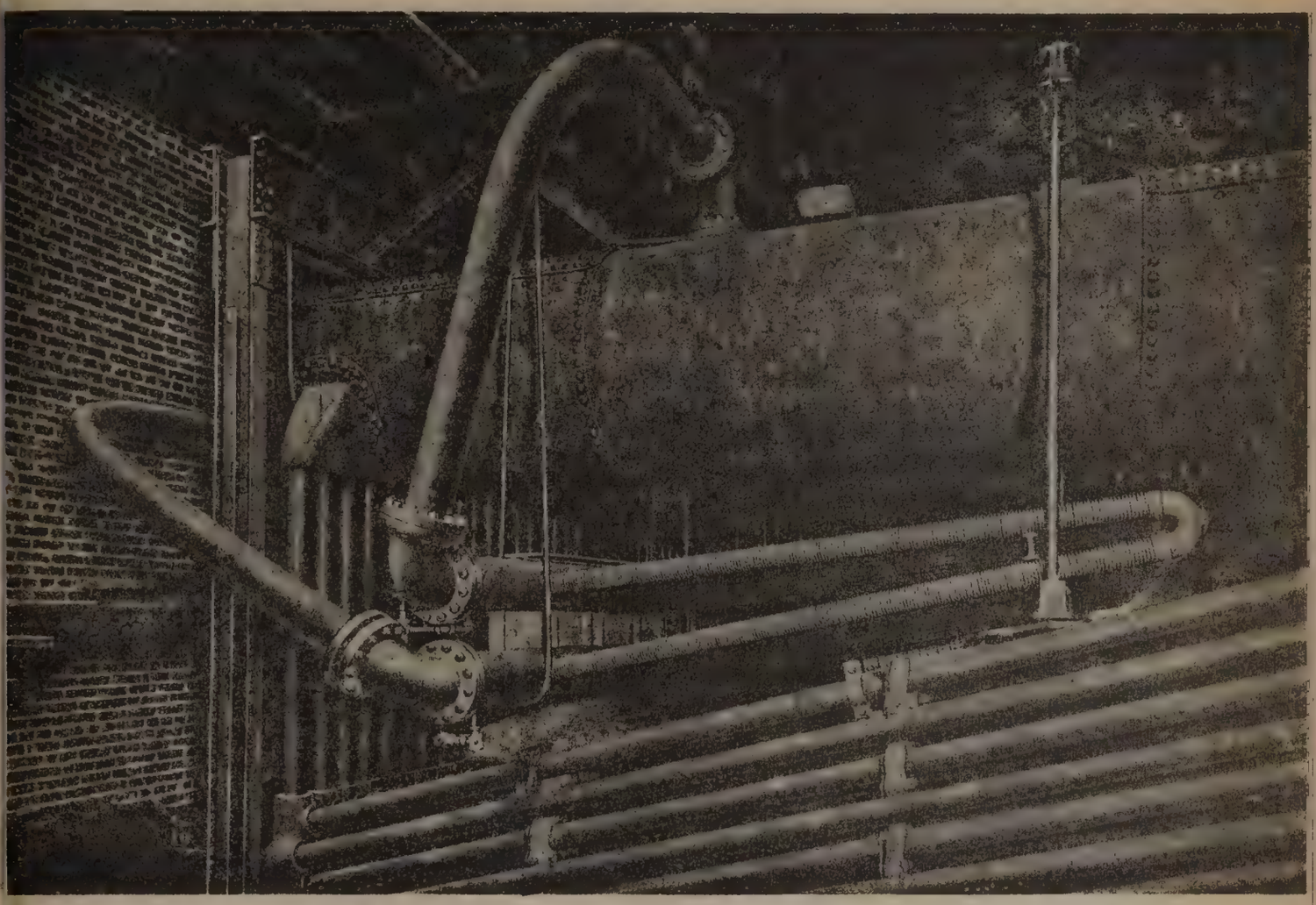
Results of tests on 46-in. and 88-in., 84-in. and 84-in. by 60-in. Allis-Chalmers Cross-compound Blowing Engine

Item	Unit	Saturated steam				Superheated steam		
	..	C	C	C	C	C	C	C
1. No. of test	.....	11	12	13	14	22	23	24
2. Date	.....	March 30	March 31	April 1	April 18	Aug. 5	Aug. 8	Aug. 9
3. Duration	hours	5	5	5	4.83	4.5	4	3.5
4. Blast pressure	lb. sq. in.	11.71	12.17	13.31	14.06	13.31	14.30	13.89
5. Speed	r.p.m.	39.45	39.53	39.09	40.16	38.80	38.16	38.83
6. Delivered horsepower	hp.	1384	1428	1510	1614	1490	1554	1545
7. Indicated horsepower	hp.	1465	1512	1580	1681	1570	1614	1613
8. Mechanical efficiency	per cent.	94.5	94.5	94.6	96.0	95.4	96.2	95.8
9. Pressure at throttle valve (gauge)	lb. sq. in.	133.2	133.4	131.6	134.0	136.7	137.0	136.1
10. Quality steam at throttle	per cent.	98	98	98	98	.....	.....	.....
11. Superheat at throttle	deg. fahr	.....	.....	.....	.....	116	110	112
12. Exhaust pressure (absolute)	lb. sq. in.	5.19	4.7	4.86	4.3	3.72	3.96	4.04
13. Total steam per hour	lb.	24060	24420	24100	24490	20560	21525	21430
14. Total steam per hour (dry)	lb.	23580	23920	23620	23990	.....	.....	.....
15. Steam per i.hp. per hour (dry or superheated)	lb.	16.10	15.83	14.95	14.26	13.10	13.35	13.30
16. B. t. u. per i. hp. per minute	B. t. u.	285.	280.5	265.	254.1	249.	252.6	251.4

Average of series of above tests	Unit	Saturated steam	Percentage of saving	Superheated steam
Initial pressure	lb. gauge	133	.....	136.6
Superheat	deg. fahr.	.....	.....	113.
Back pressure	lb. abs. sq. in.	4.76	.....	3.91
Average dry or superheated steam per i. hp. per hour	lb. sq. in.	15.28	.....	13.25
Saving due to superheat (steam)	per cent.	.....	13.33	.....
Average B. t. u. per i. hp. per minute	.....	271.2	.....	251.0
Saving due to superheat (B. t. u.'s)	per cent.	.....	7.43	.....

Results of tests on 75-in. and 84-in. by 60-in. Southwark Vertical Blowing Engine operated as simple engine

Item	Unit	Saturated steam	Superheated steam
		B	B
1. No. of test	.....	13	21
2. Date	.....	April 13	Aug. 15
3. Duration	hours	4.5	5
4. Blast pressure	lb. sq. in.	17.4	14.83
5. Speed	r.p.m.	40.65	32.78
6. Delivered horsepower	hp.	971	697
7. Indicated horsepower	hp.	1022	729
8. Mechanical efficiency	%	95	95.6
9. Pressure at throttle valve (gauge)	lb. sq. in.	131.5	138
10. Quality steam at throttle	%	98	.....
11. Superheat at throttle	deg. fahr.	.....	98
12. Exhaust pressure (absolute)	lb. sq. in.	4.8	3.5
13. Total steam per hour	lb.	28430	16880
14. Total steam per hour (dry)	lb.	27850	.....
15. Steam per i. hp. per hour (dry or saturated)	lb.	27.25	23.17
16. B. t. u. per i. hp. per minute	B. t. u.	483	437.6
Per cent. saving steam 14.97	.....	.....	.....
Per cent. B. t. u.'s 9.40	.....	.....	.....



Foster Superheater in a 500-hp. Babcock & Wilcox Longitudinal-drum Horizontal Water-tube Boiler. One of twelve installations in similar units at the Schoellkopf plant of the National Aniline & Chemical Co., Buffalo, N. Y.

superheat is sufficient to not only carry the steam dry throughout the piping system but also to deliver it superheated to engines, turbines and pumps at various points in the plant.

Benefits in Reciprocating Engines

THE advantage of superheated steam when supplied to an engine or pump comes from the reduction or total elimination of cylinder condensation caused by the steam coming into contact with the relatively cool surface of the cylinder. In the case of saturated steam, this cylinder condensation loss causes a considerable percentage of steam to break down into water and the resulting loss of volume requires additional steam to be supplied to the cylinder to fill it up to the point of cut-off.

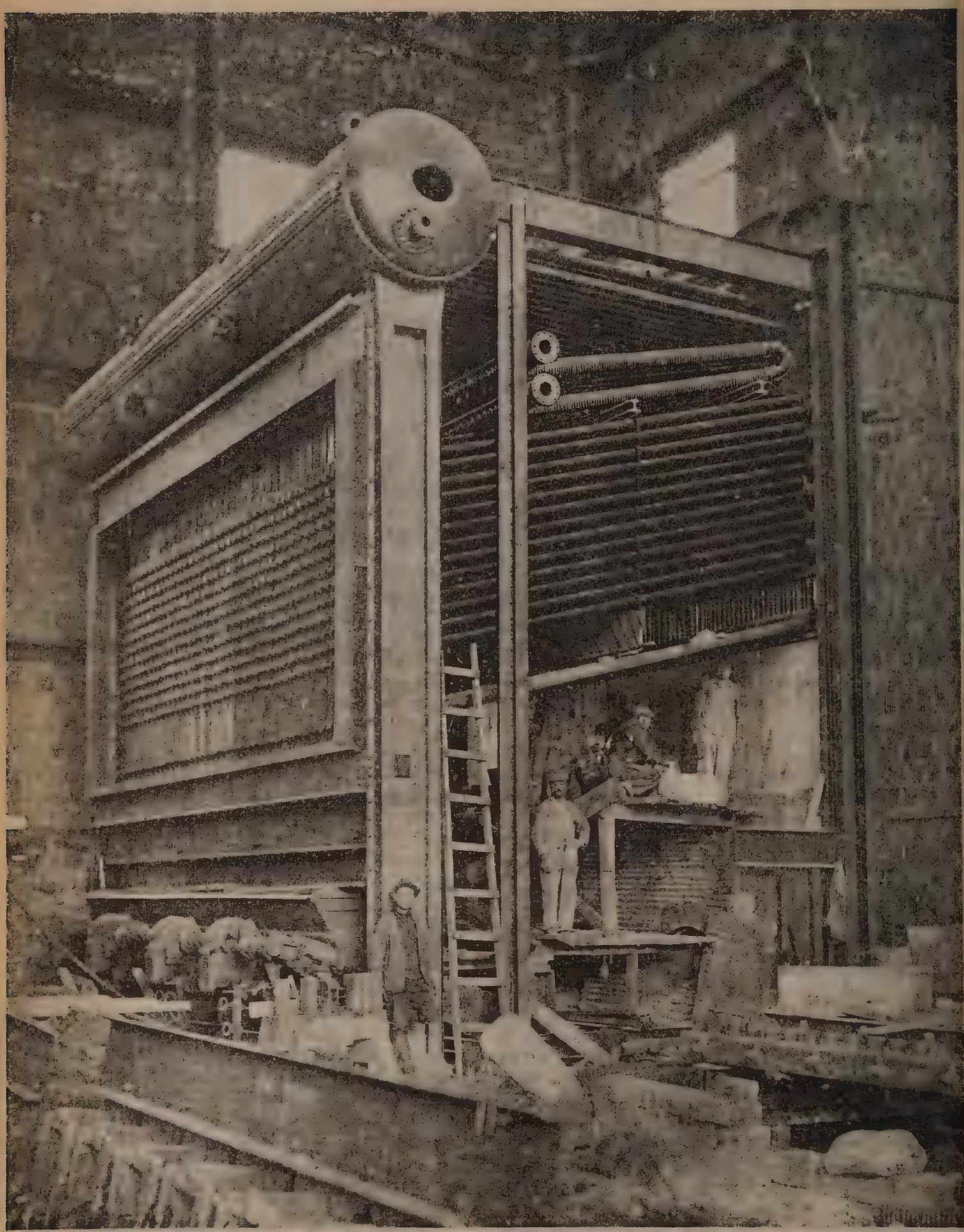
Steam may be sufficiently superheated when entering an engine cylinder to entirely overcome this cylinder condensation loss and even to supply steam dry all the way through to exhaust. It will be seen that in this way the steam required per stroke may be greatly reduced, and very considerable economy obtained.

The value of dry steam in the cylinder from the standpoint of lubrication is also considerable. Wet steam will wash away the oil, whereas with dry superheated steam the oil film will remain on the cylinder surfaces and much less oil will insure perfect lubrication.

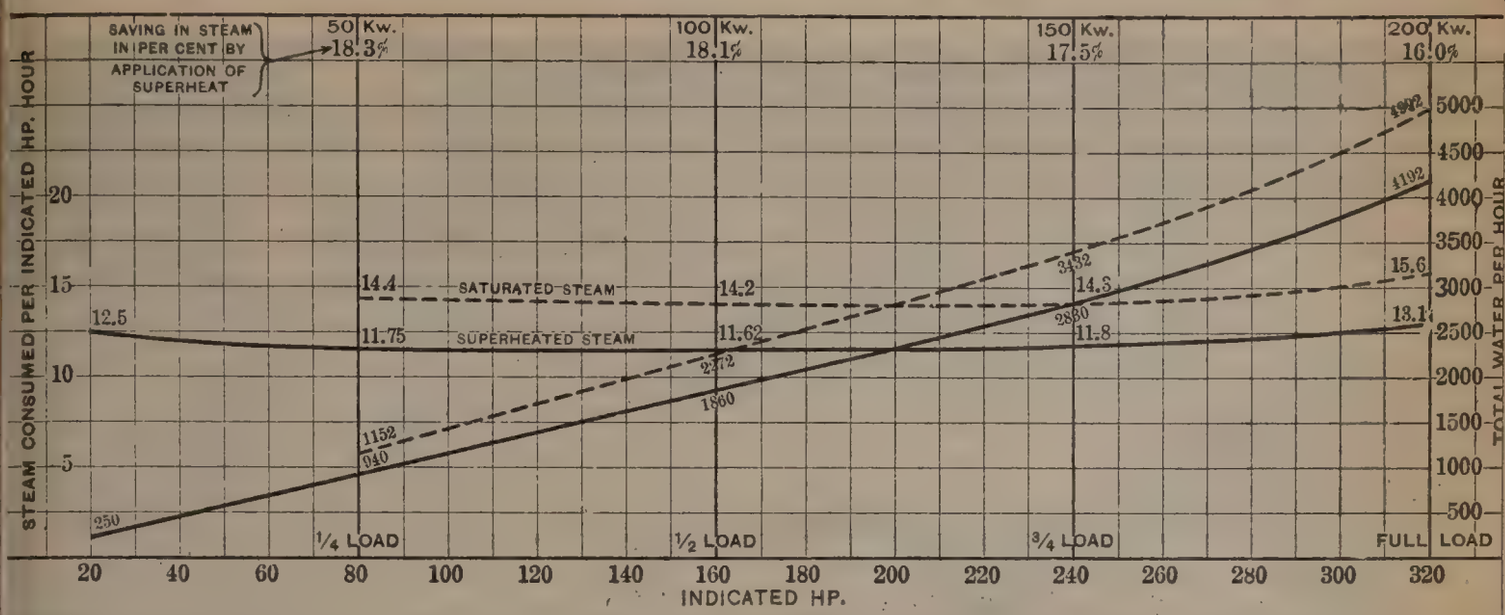
The degree of superheat most suitable for each type of engine depends somewhat upon the valves, as certain types are better able than others to take care of expansion.

In the case of slide-valve and Corliss-valve engines, the steam should not be delivered at the engine with a final temperature exceeding 475 deg. to 500 deg. fahr. Plants having this type of equipment and using about 150-lb. steam pressure can obtain excellent results by using 75 to 100 deg. of superheat. If the pressure is low, a somewhat higher degree of superheat may be used, as the resulting final temperature will not be as high as when the pressure is high. For conservative figuring, we suggest that the final temperature should not be more than 475 deg. fahr.

Engines of the piston valve or poppet valve types may utilize much higher degrees of superheat, with resulting greater economy in steam. In such engines, if the higher economy is desired,



Foster Superheater in a Babcock & Wilcox Cross-drum Boiler. One of four similar 1232-hp. units in the plant of the Appalachian Power Co., Glenlyn, Va. Seven more units have recently been installed



The improvement in water rate effected in a 320 i. hp. 18-in. by 24-in. Ames Una-flow Engine when operated with superheated instead of dry saturated steam. The engine tested was direct-connected to a 250 kva. generator. Speed, 200 r.p.m. Initial steam pressure at throttle, 146 to 149 lb. Superheat applied, 106 to 107 deg. fahr. Admission steam temperature, 470 to 473 deg. fahr. Vacuum at exhaust nozzle, 23 to 24 inches. Foster Superheater used to obtain superheat

150 to 250 deg. superheat may easily be used.

Where moderate degrees of superheat are used on the main engines of a plant, superheated steam should be used on the steam-driven auxiliaries. The saving obtained by the use of superheated steam on direct-acting pumps is very high and full advantage should be taken of this economy in the plant.

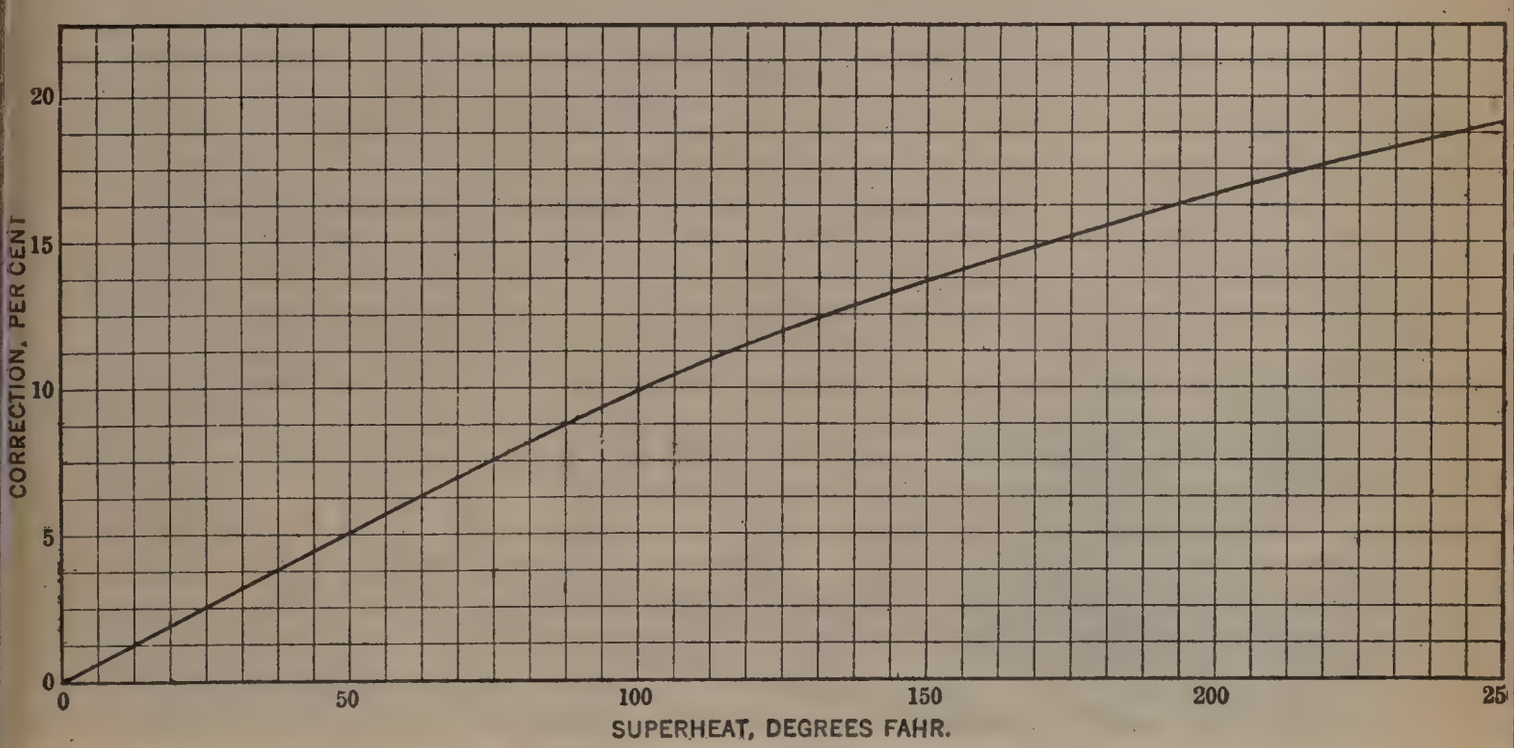
The savings that may be expected in engines with a moderate degree of superheat (100 deg. fahr.) are given in the following table:

Type of engine	*Steam saving*
Simple engine	18 to 20 per cent
Compound engine	14 to 15 per cent
Triple-expansion engine	10 to 12 per cent
Direct-acting pumps	20 to 30 per cent

Economy tests of different types of engines are given in tables, Page 4 and curve above.

Advantages in Steam Turbines

SUPERHEATED steam is particularly desirable for use in the steam turbine, not only from the standpoint of steam economy but also

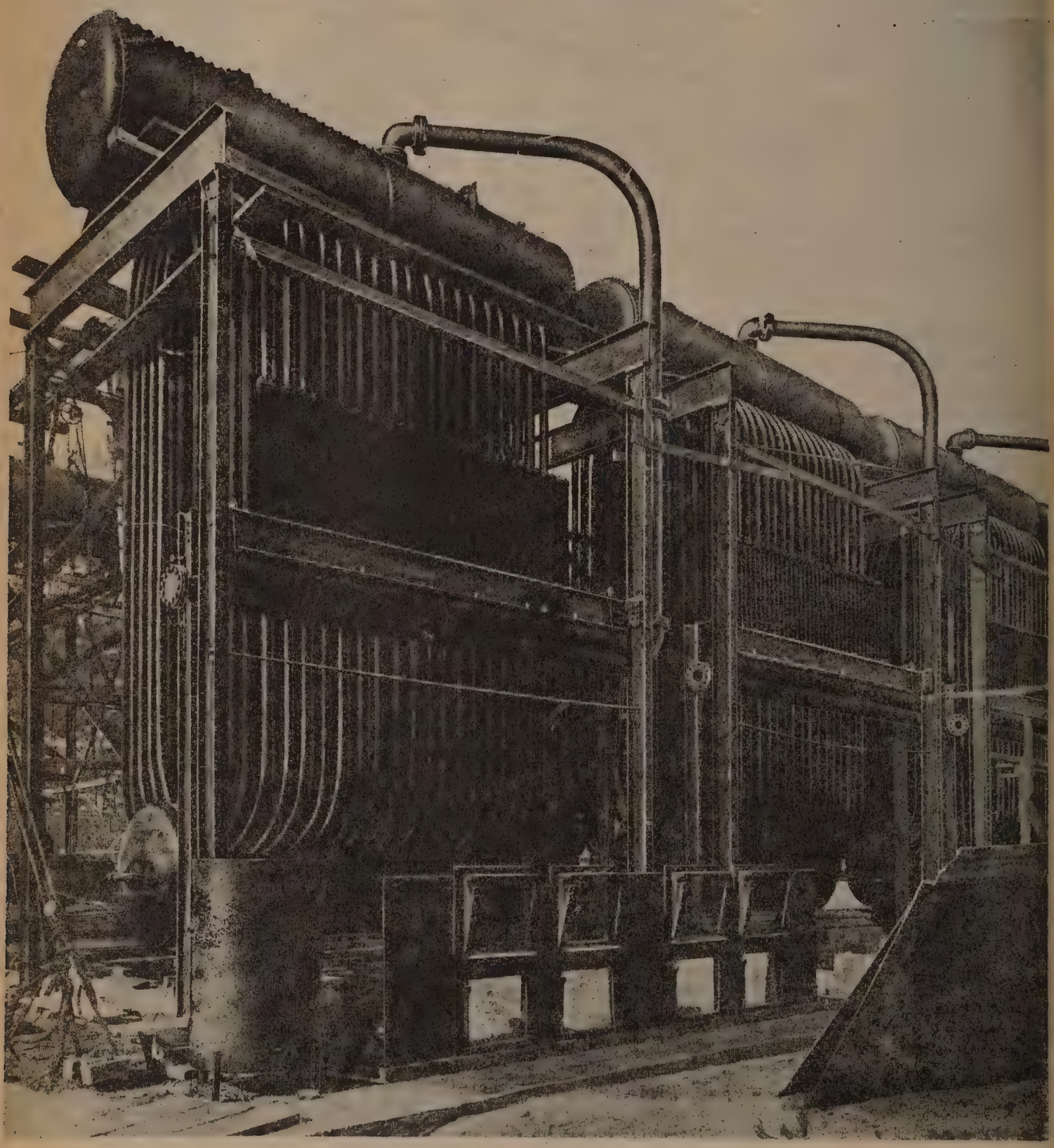


(Published by courtesy of Westinghouse Electric & Mfg. Co.)

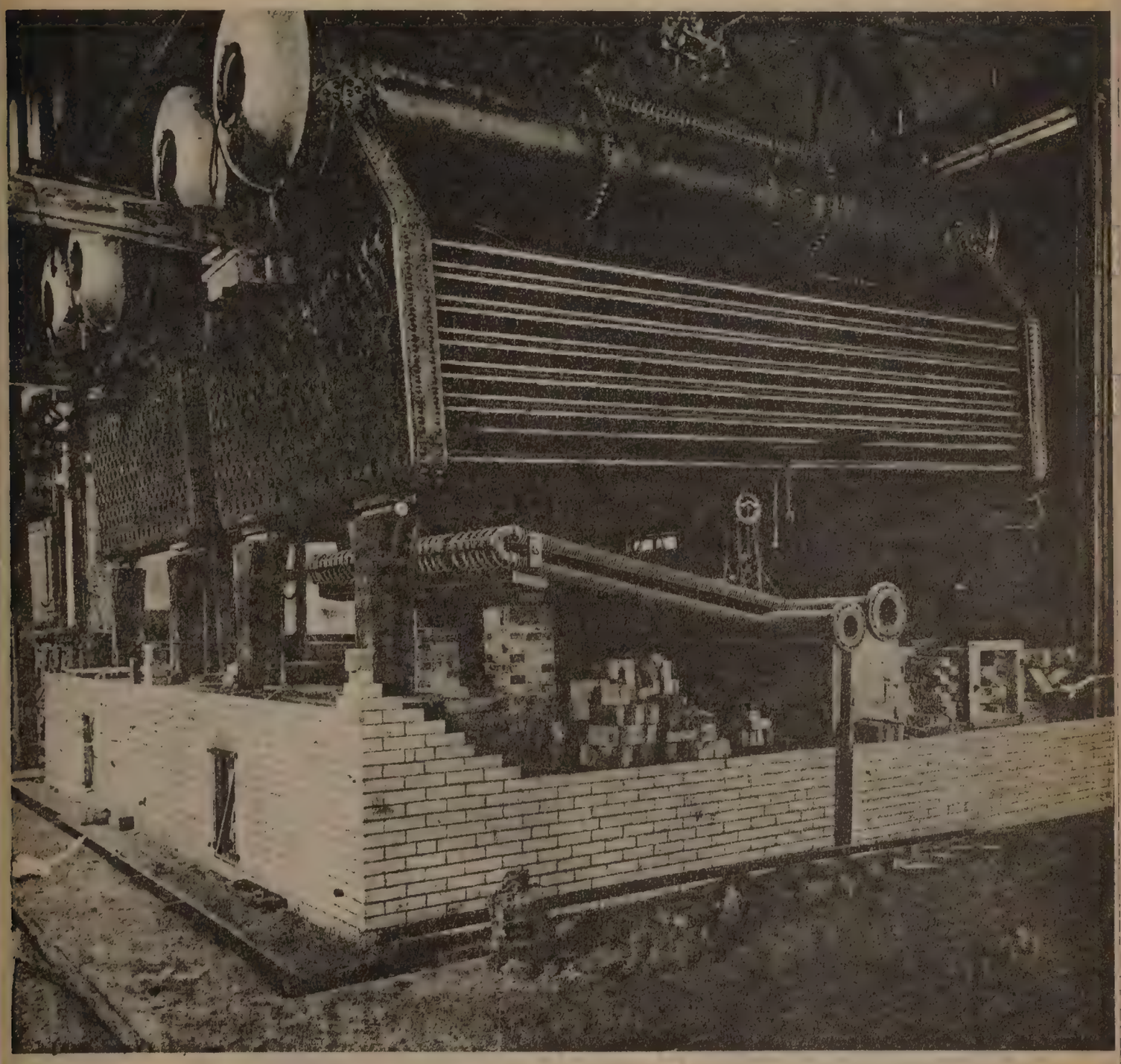
Correction or saving to be figured in the water rate of steam turbines when superheated instead of saturated steam is used

on account of the elimination of wear on turbine blading from moisture entrained in the saturated steam. Steam passes through a turbine at high velocity and any water contained in it soon causes wear on the blades, thus increasing the clearance and decreasing the economy of the turbine unit.

Turbines may be designed for the use of high degrees of superheat. The improvement in steam economy obtained up to 100 deg. of superheat amounts to approximately 1 per cent for each 10 deg. of superheat delivered at the throttle. The percentage of saving obtained from higher



Foster Superheaters in twelve 400-hp. Erie City Vertical Boilers at the plant of Jones & Laughlin Steel Co., Woodlawn, Pa. The arrangement of the superheater is similar to that for Ladd Boilers, as shown on Page 16

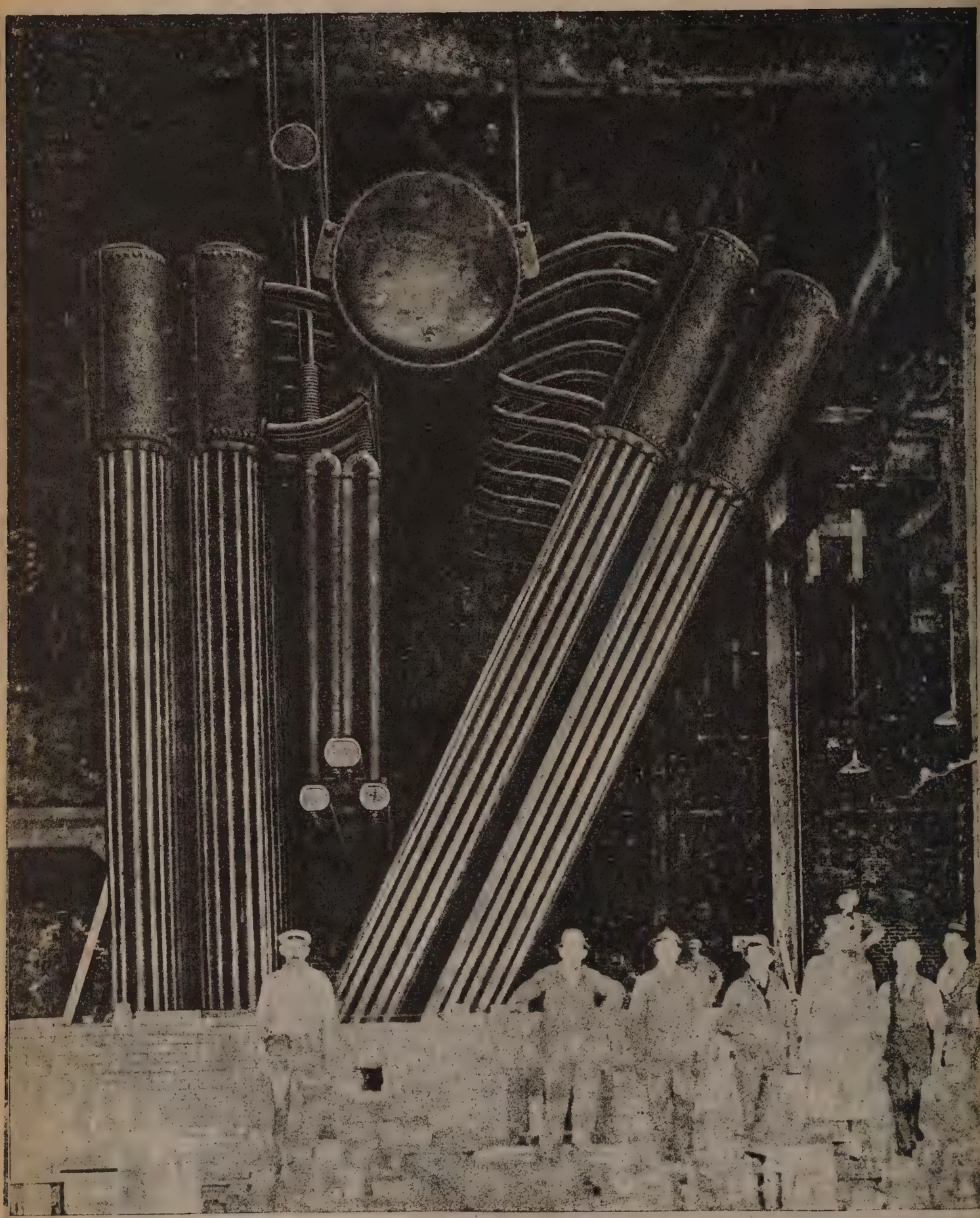


Foster Superheater in O'Brien Boilers in the St. Louis (Mo.) Water Works. In this arrangement the superheater is located in the space below the boiler tubes and behind the bridge wall. The headers are protected not only by the bridge wall but by tile projecting over them from the top of the bridge wall. Headers are supported upon pedestals from the floor, while the elements at the further end rest upon a chair or plate supported by pedestals from the floor. Connection is made between the boiler outlet nozzle and the superheater inlet nozzle by means of a pipe bend. This arrangement is also used in horizontally baffled boilers of the following makes: Heine, Erie City, Franklin, Walsh & Weidner, Kroeschell and Murray

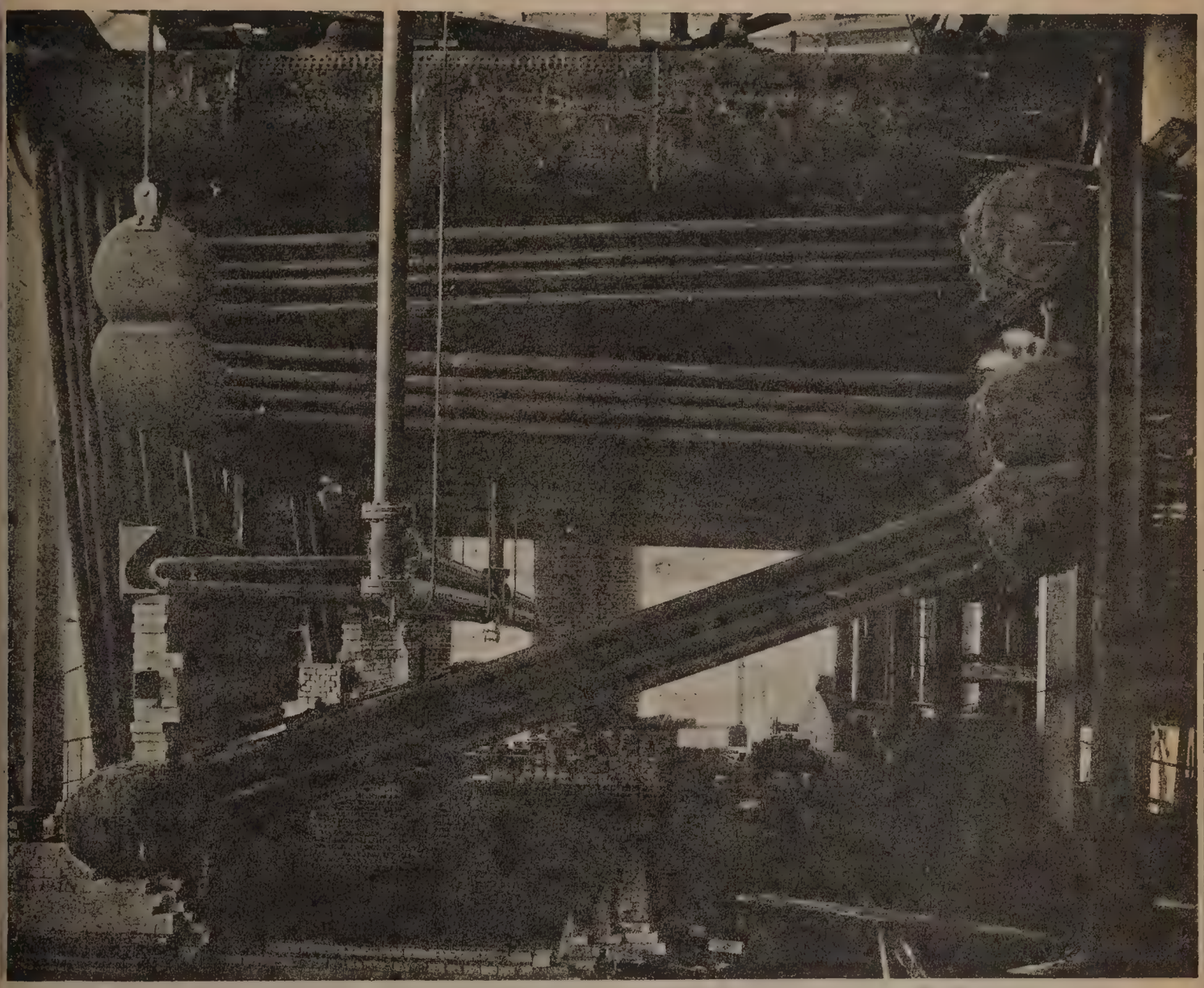
degrees of superheat is slightly less. A typical curve showing economy in steam turbines due to the use of superheated steam and the saving as compared with using dry saturated steam is shown in the illustration, Page 7. Saturated steam is never delivered at the turbine dry, but generally arrives with approximately 2 per cent of moisture. The turbine builder makes a correction of 2 per cent for each 1 per cent of moisture present when the steam reaches the turbine, so that if the steam originally contains 2 per cent of moisture a further saving of 4 per cent is accomplished by eliminating this moisture in the superheater.

Effect of Superheat Upon the Vacuum

THE use of superheated steam on condensing engines and turbines has an effect upon the vacuum obtained. A smaller weight of steam is



One of four Foster Superheaters installed within the settings of four 750-hp. Bigelow-Hornsby Boilers at the plant of Niagara, Lockport & Ontario Power Company, Lyons, N. Y. The superheater is entirely suspended from above, giving free expansion, and is double-decked to obtain a high degree of superheat. Superheaters have since been installed in three 1000-hp. units



One of the Foster Superheaters installed within the settings of twelve 500-hp. Vogt Boilers at the p ant of the Standard Oil Company of Indiana, Sugar Creek, Mo. The superheater headers are suspended from the boiler drums by means of air-cooled U-bolts, while the elements of the superheating surface at the end furthest from the headers rest upon cast-iron chairs or plates, which in turn are supported by the rear baffle wall of the boiler. The inlet and outlet connections from the superheater are outside the boiler wall and the inlet is connected to the boiler outlet by means of a pipe bend

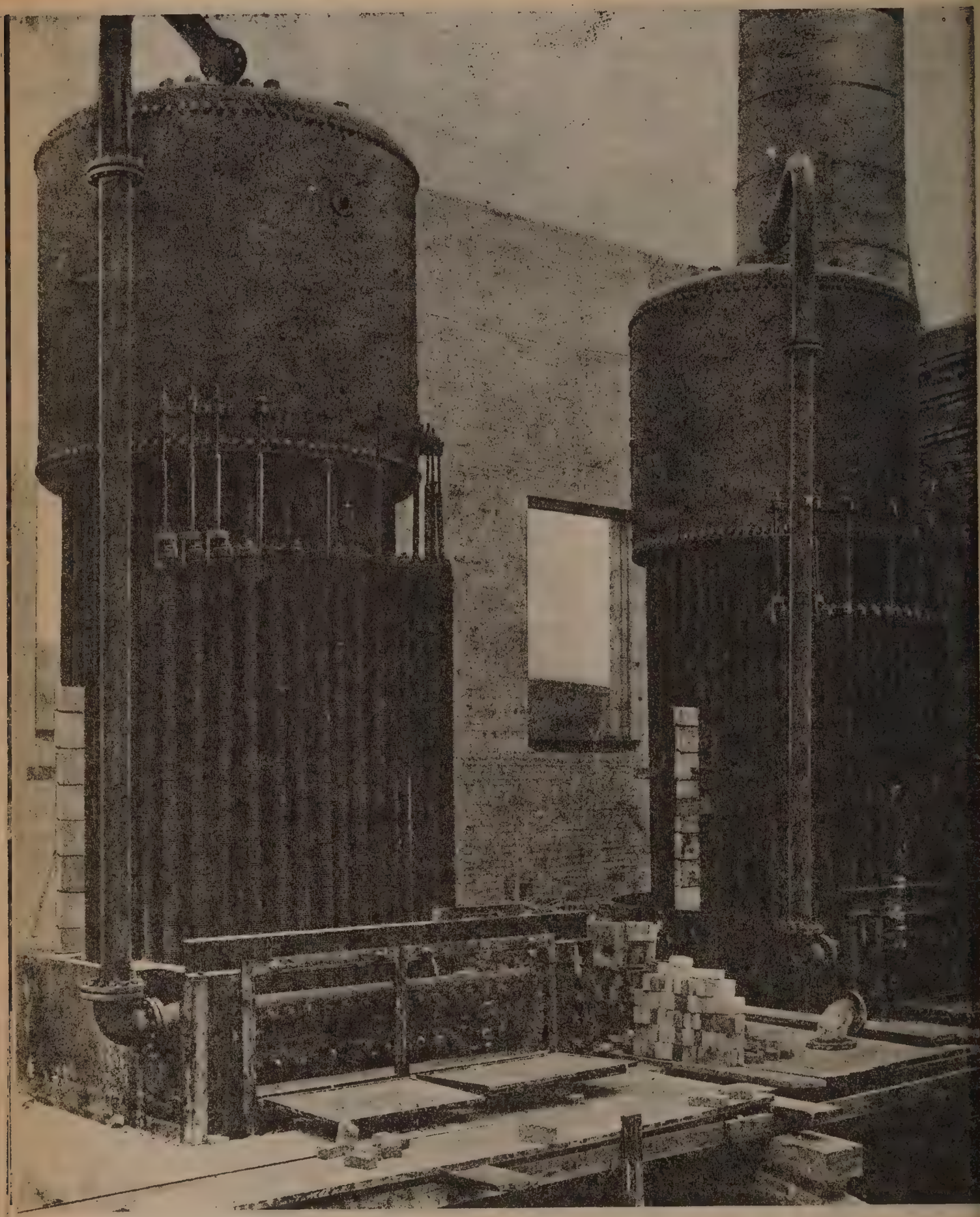
used to produce a given power and therefore the weight of the exhaust is less, thus relieving the condenser of part of its load, and increasing the vacuum and economy of the unit.

Piping and Fittings for Superheated Steam Lines

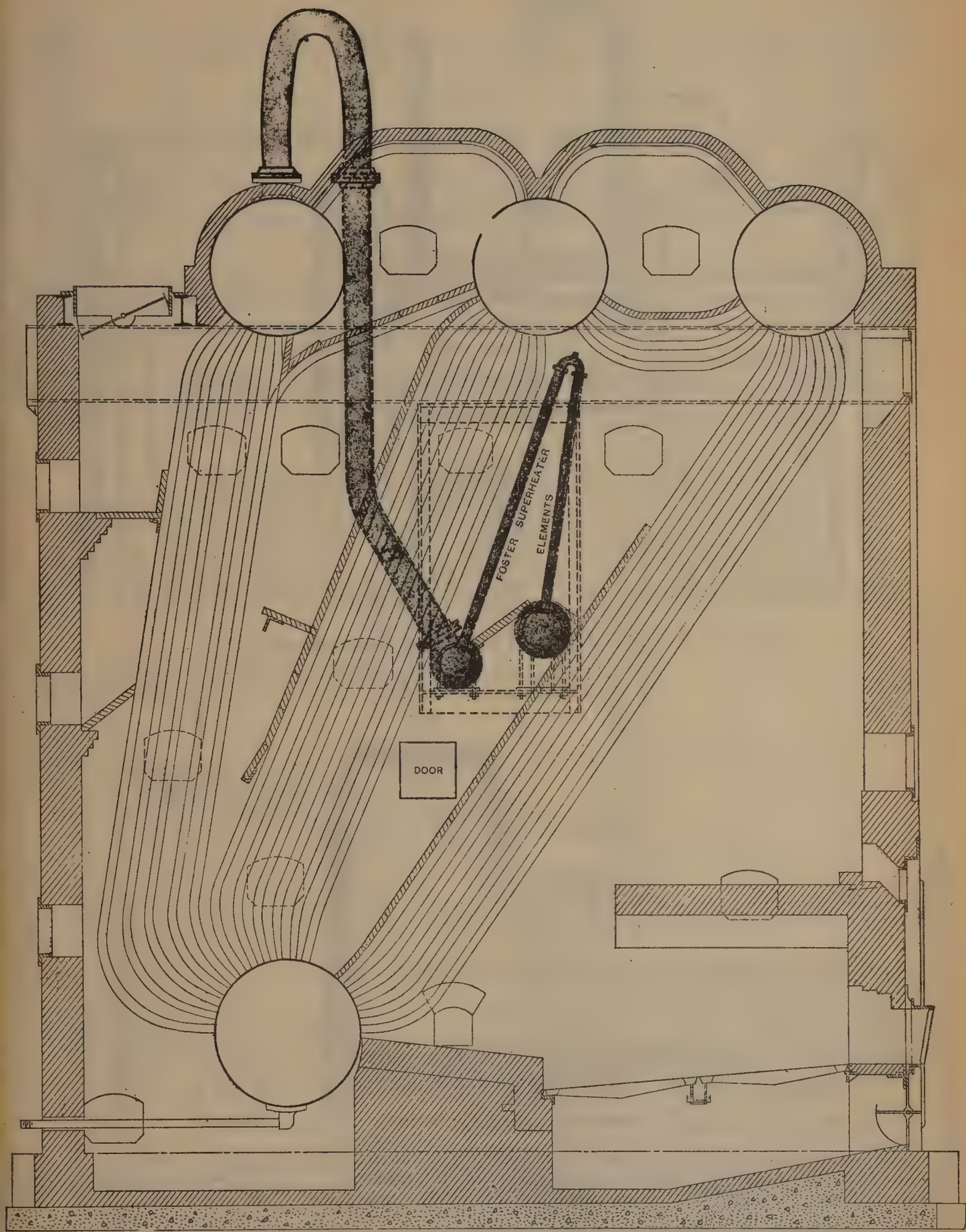
THE use of superheated steam in any power plant involves consideration of the piping system. In existing plants where the piping, valves and fittings were designed for use with saturated steam, a moderate degree of superheat is best. Where the piping system is made up with standard weight cast-iron valves and fittings, and where the pressure is low, say not more than 100 to 125 lb., not more than 75 to 100 deg. of superheat should be employed.

If the piping system contains extra heavy cast-iron valves and fittings, with ample allowance for expansion, higher degrees of superheat can be used without difficulty up to a final temperature of 500 deg. fahr. Some attention in existing plants may have to be given to the gaskets used in making up flange joints. The material used for gaskets must be able to withstand the higher temperatures of superheated steam without being impaired by the greater expansion and contraction, which result from the wider temperature range.

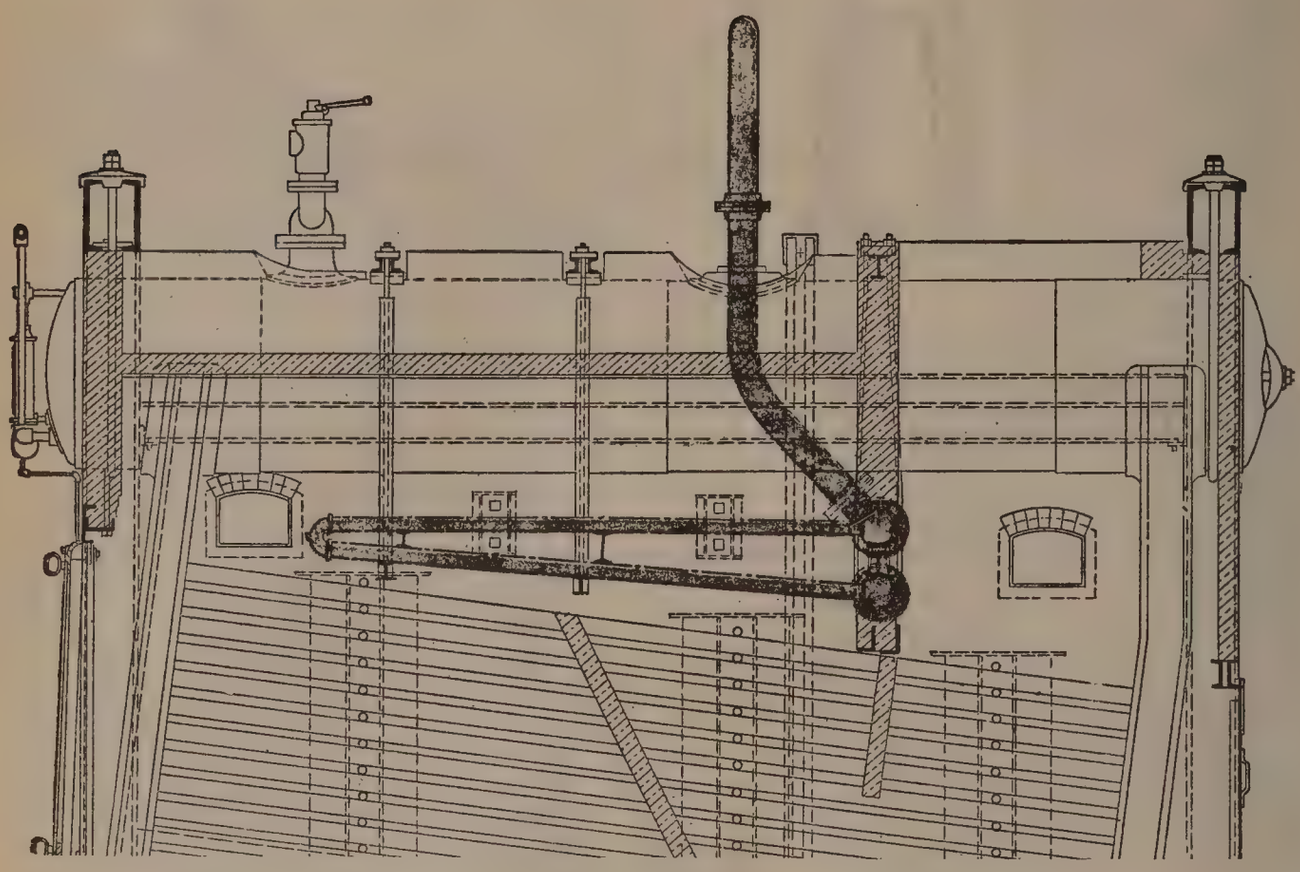
In all plants designed for high pressure and high superheat the valves and fittings should be of steel, and the piping system should have provision for ample expansion.



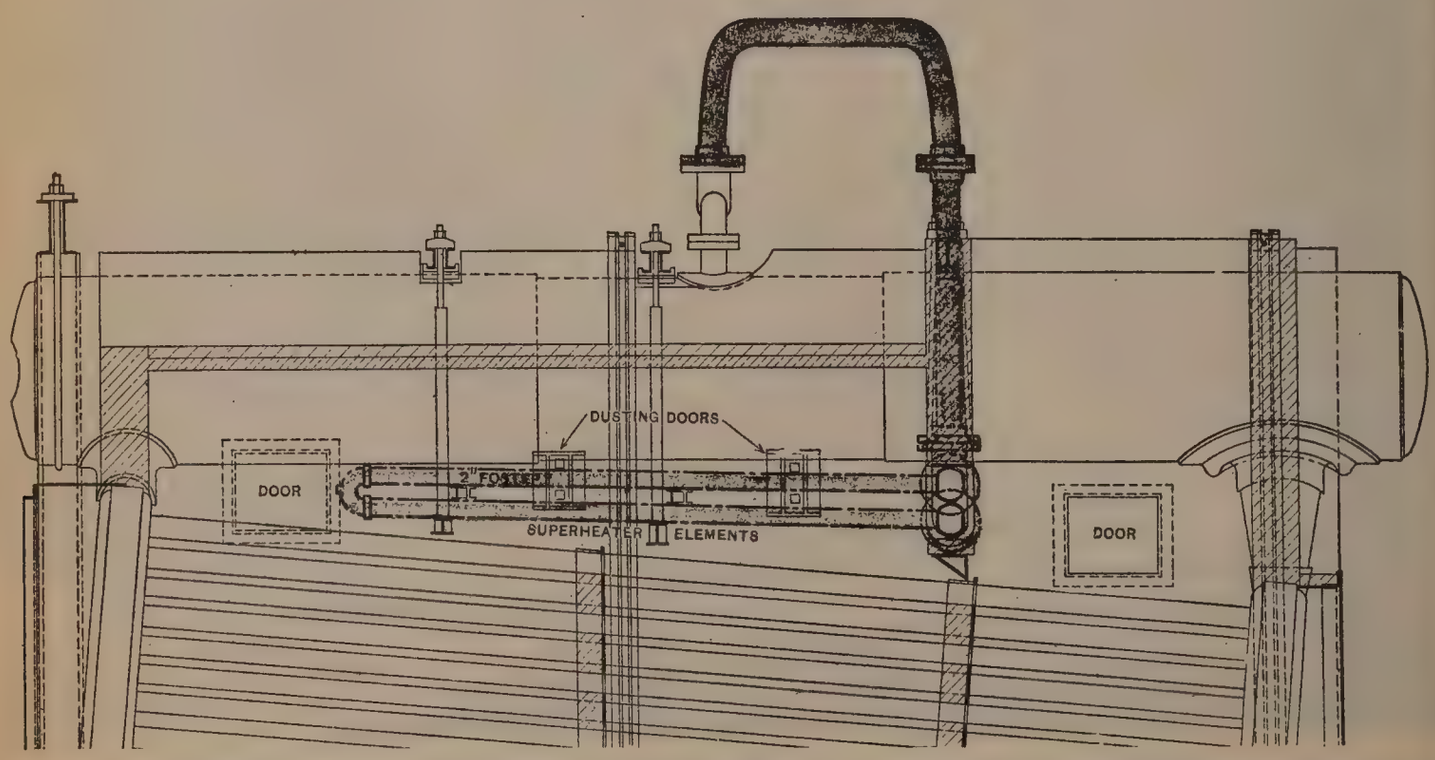
Two of the six Foster Superheaters installed in six 500-hp. Wickes Vertical Water-tube Boilers at the plant of the Kalamazoo (Michigan) Paper Company. The superheater inlet and outlet headers are placed horizontally in front and above the furnace arch. The elements rest in a vertical position and are located between the boiler tubes and the front setting wall. They are supported by hanger bolts from lugs riveted to the top drum of the boiler



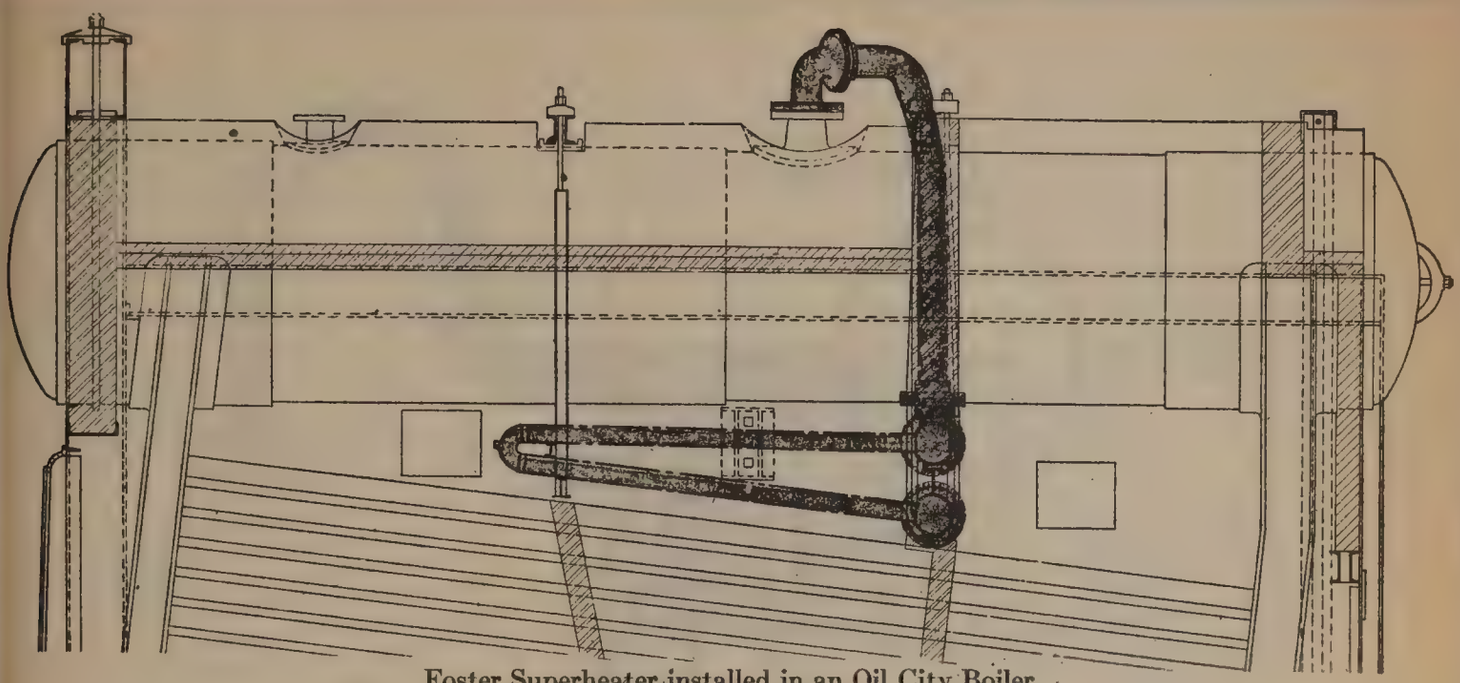
Typical application of the Foster Superheater to the Stirling Boiler. The superheater is located between the first and second banks of boiler tubes and suspended in position by means of a structural framework fastened to the boiler framing. The connections to the superheater are outside the boiler setting, the inlet being connected to the boiler outlet nozzle by a pipe bend



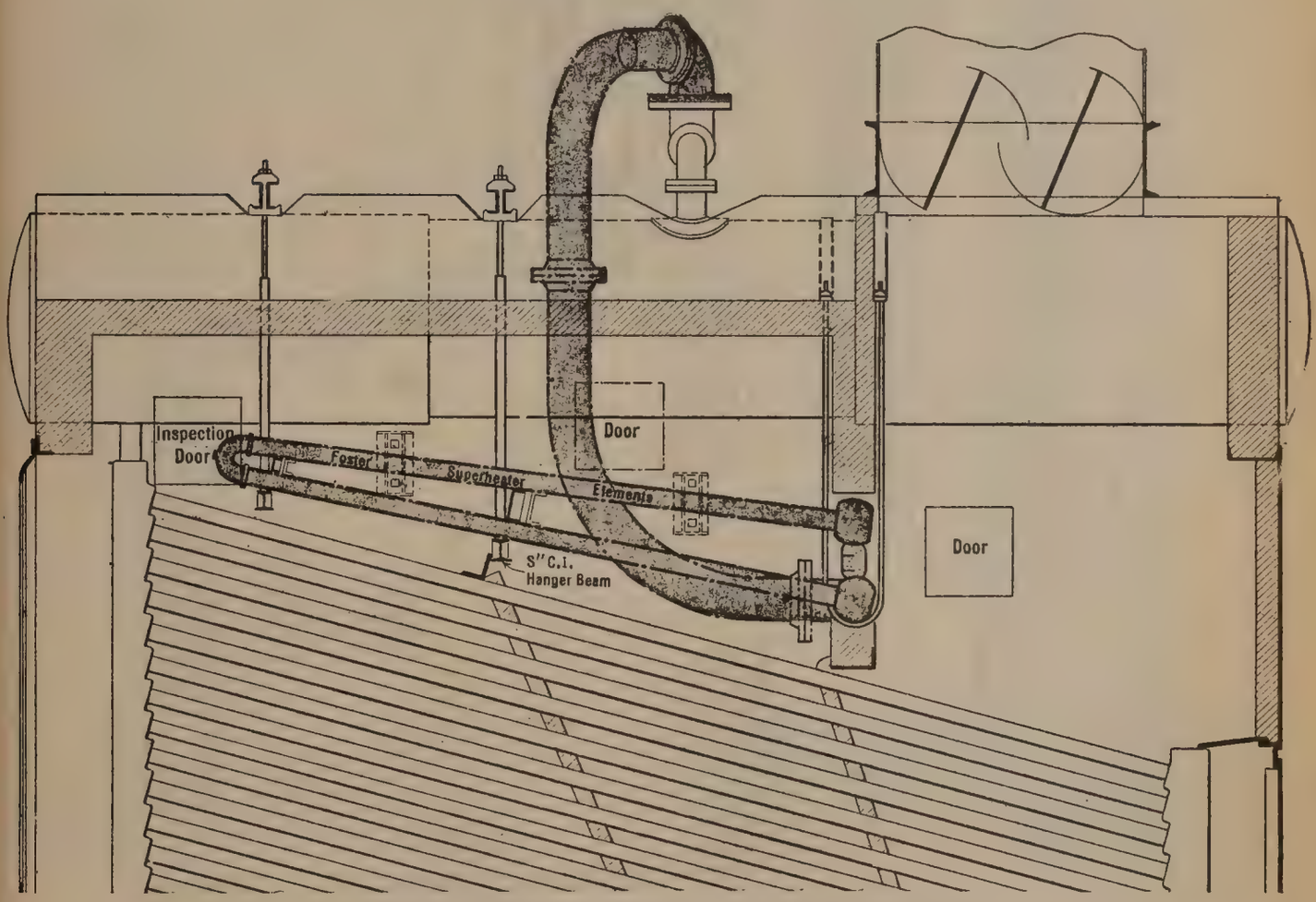
Foster Superheater installed in a Casey-Hedges Longitudinal-drum Boiler



Foster Superheater installed in a Union Boiler. See caption at bottom of Page 15

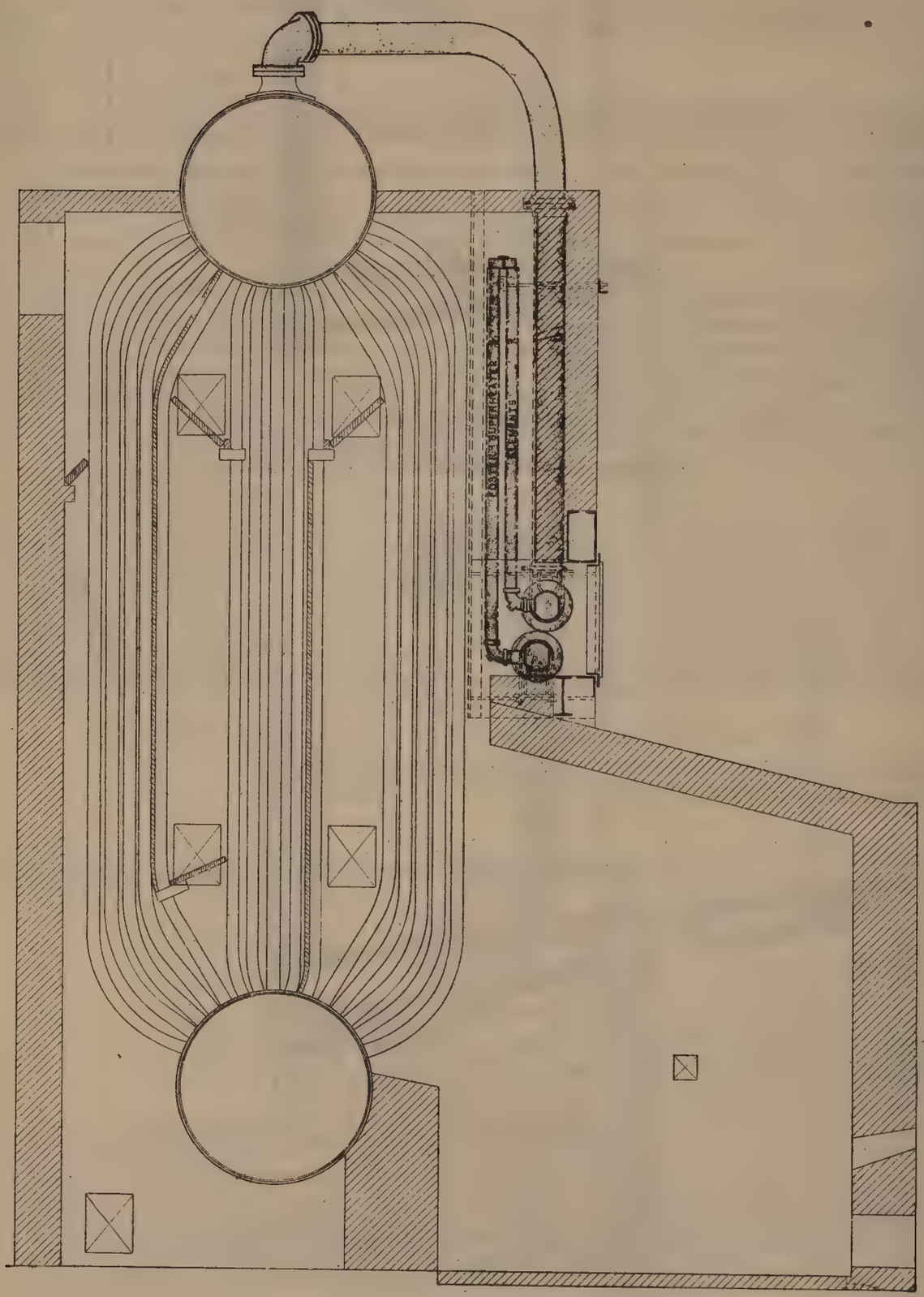


Foster Superheater installed in an Oil City Boiler

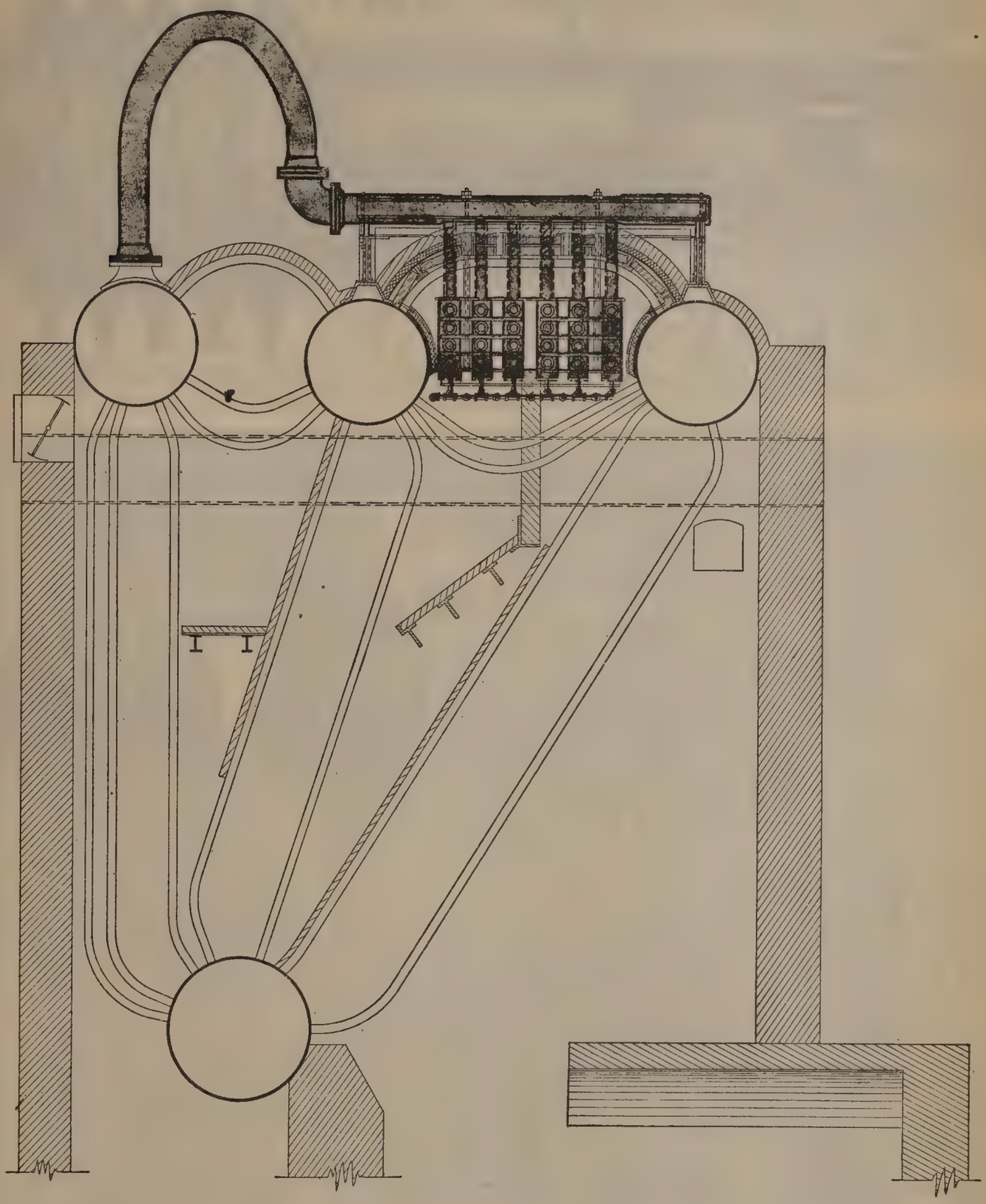


Foster Superheater installed in a Kingsford Boiler

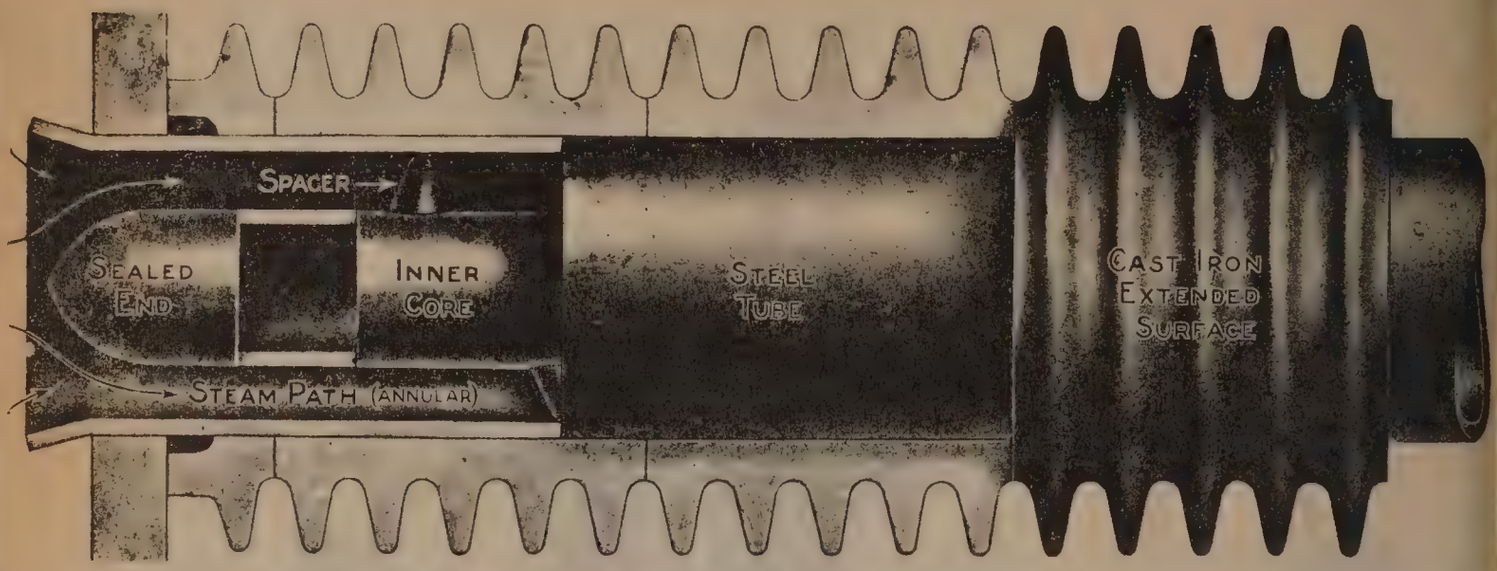
The above and the two elevations on Page 14 are typical of the standard superheater arrangement in vertically baffled longitudinal-drum water-tube boilers. The elements lie in the space between tubes and drum above the first and second passes, and the headers form part of the hanging bridge wall above the second boiler baffle. The superheater is supported by U-bolts under the headers, and cast-iron beam or beams under the elements, the bolts and beams being suspended from overhead structural steel framework. The superheater is connected to the boiler preferably by pipe bend carried down from the boiler outlet nozzle or cross-pipe flange to the flange on the superheater inlet, which is located outside the boiler setting. The delivery pipe is connected to a similar flange on the superheater outlet, which also extends through the side wall of the setting. Similar arrangement is used also with Babcock & Wilcox, Wickes Horizontal, Freeman, Keeler, Walsh & Weidner Longitudinal-drum, Goldie & McCulloch, O'Brien, Bass, Kroeschell, Erie City, Heine, and other vertically baffled horizontal water-tube boilers



Typical application of the Foster Superheater to the Ladd Boiler. Superheating surface is arranged vertically and located between the front bank of boiler tubes and the front wall of the setting. The headers are placed across the front of the boiler above the combustion arch, and are supported by framework tied into the boiler framing. The inlet and outlet connections are outside the setting wall, and connection is made to the boiler nozzle by means of a pipe bend. A similar arrangement is used also in O'Brien Vertical Boilers



Design of Foster Superheater for Heine V-type Boiler. The boiler is baffled to direct the flow of gases over superheating surface between the upper front and middle drums. The superheater inlet and outlet manifolds above are connected to vertical headers in the side walls of the setting by vertical tube nipples. The manifolds are supported on a steel frame and cast-iron pedestals on the boiler drums, and the vertical headers on the tube nipples expanded into the manifolds. The elements are supported at intermediate points by cast-iron hanger beams and bolts, the latter protected by pipe sleeves. The boiler outlet and superheater inlet are connected by pipe bend, and the superheater outlet is at the opposite side of the boiler



Typical Foster Extended Superheating Surface. (Patented.) A short uncovered portion at each end of the tube permits the ends to be inserted and expanded into the connecting headers

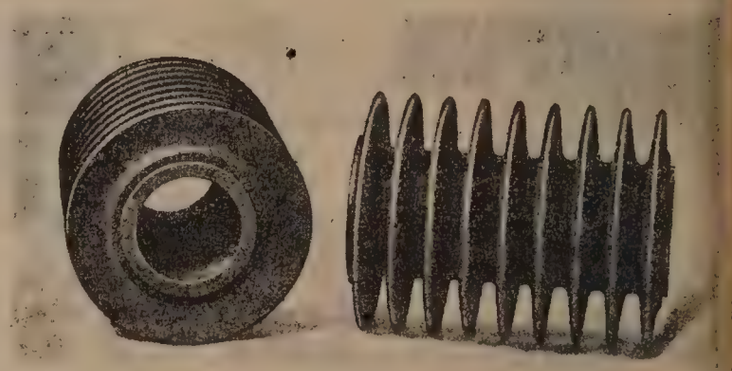
Foster Extended Superheating Surface

INASMUCH as the unique construction of superheating surface in Foster Superheaters has for twenty-five years had no equal for its purpose and has been more used than all other designs put together, the following reasons for its supremacy should be thoroughly understood by all interested in the production and use of superheat.

1. *Steel for strength, cast-iron for durability*: The seamless steel tubes are designed to withstand a bursting pressure several times that of service, and the surrounding rings more than double the actual resistance to bursting. Only the tough original skin of the cast-iron, which is practically immune to burning and corrosion, is exposed to the gases.

2. *Four to six times as much heat absorption surface as obtained from bare tubes*: The extended surface of the rings gives a better balance for heat conductivity from the slow-moving low-density hot gas in contact with the exterior, to the larger weight of fast-moving steam wiping the interior. By thus increasing the heat transfer per unit length of element, the construction of a superheater to fulfil a given specification is simplified. This is of the greatest advantage in cases where superheaters have to be placed in relatively restricted and inaccessible locations inside boiler settings. The high rate of heat transfer with Foster Extended Surface permits higher degrees of superheat to be obtained within the space available within the boiler than can be secured with any other type of superheater.

3. *Reserve heat stored for sudden demands*: The mass of metal in the heating surface forms a reservoir for storing heat, where it is instantly available to assist in keeping the degree of superheat constant, and in the case of a priming boiler, to aid in flashing the moisture into steam.



Cast-iron protecting ring of special type with extra large gills for increasing the heat-absorbing surface

4. *Steam stays close to the hot tube surface*: Displacing cores within each straight run of tube compel the steam to travel in a thin annular layer close to the tube surface. These cores, which consist of pipes sealed at the ends, and held concentric with the tube by small spacing rivets, also break up and drive entering water where it flashes into steam quicker.

5. *Great flexibility of design*: Foster Extended Surface adapts itself readily to an extremely wide variation in the practical proportions, size and arrangement of the parts. This makes possible a greater superheating effect for the available space than obtainable from any other type of superheater. An ideal construction can be worked out and adapted to the interior of almost any boiler, without change in boiler design or with very little change, even for unusually high superheat.

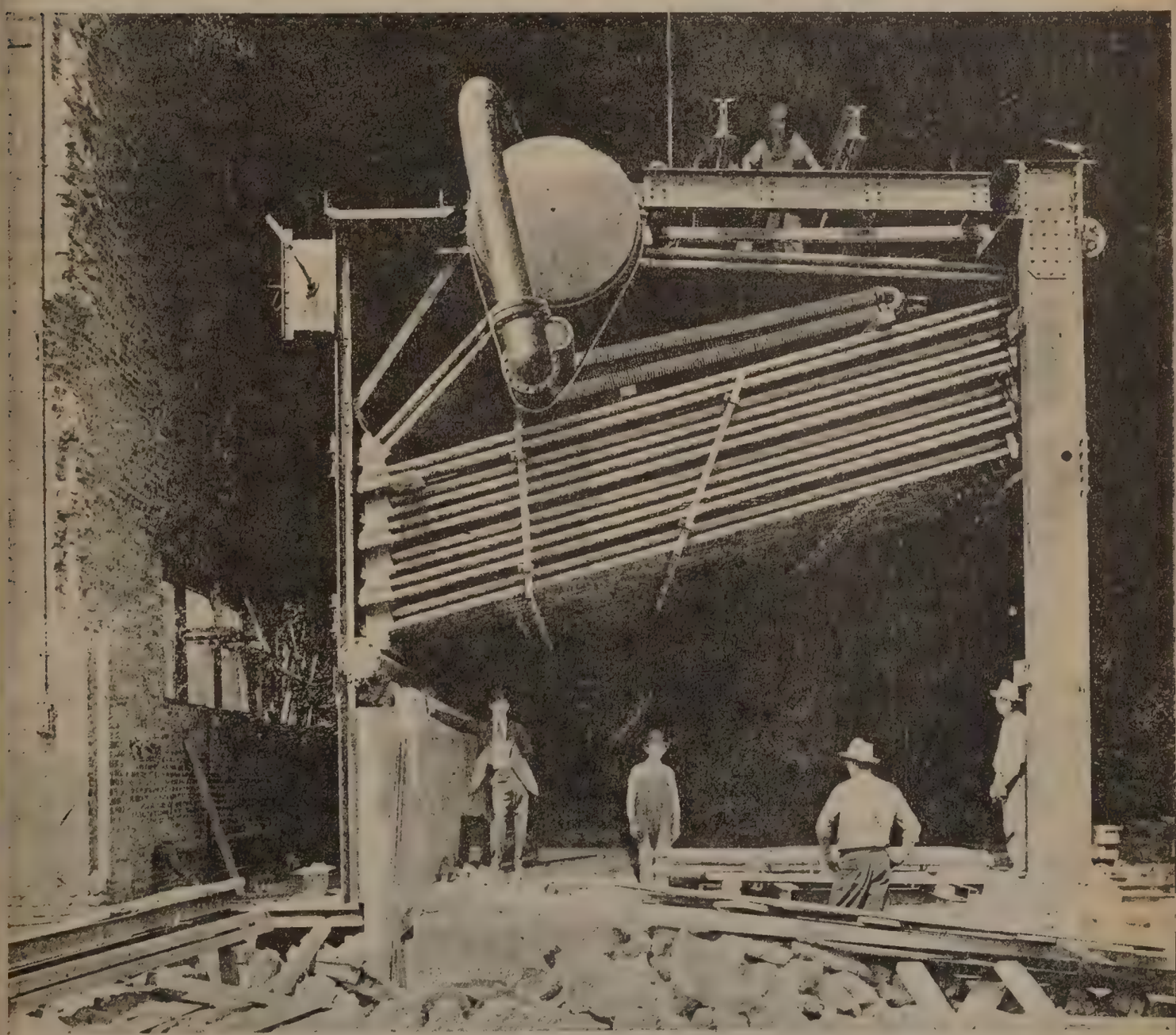
The Foster Superheater

THE Foster Superheater can be proportioned to produce any desired degree of superheat, the degree required governing to some extent the location and type of superheater used.

The superheating surface may be installed within each boiler to superheat all the steam produced by the boiler, or it may be installed in a separate brick setting with its own furnace to superheat all or any part of the steam from a number of boilers. Superheaters of the first or *attached* type will produce any degree of superheat up to 200 deg. fahr., and those of second or *direct-fired* type may be designed to superheat the steam to any final temperature up to 1000 deg. fahr.

Generally, for power plant installations the superheating surface is located within the boiler and in the path of the combustion gases, the steam being carried from the boiler outlet nozzle back through the superheating surface and out again to the steam main for distribution to the various power units.

The typical arrangements of superheating surface as illustrated throughout this booklet offer at least one practical design for each standard make of water-tube and fire-tube boiler.



Foster Superheater in Springfield Boiler. The superheater is supported by U-bolt strap around the drum and by hanger beams and rods from overhead structural steel members

Steel for streng

Typical Foster U-Shaped Superheating Element showing construction at header and on opposite page at bend

Design and Construction

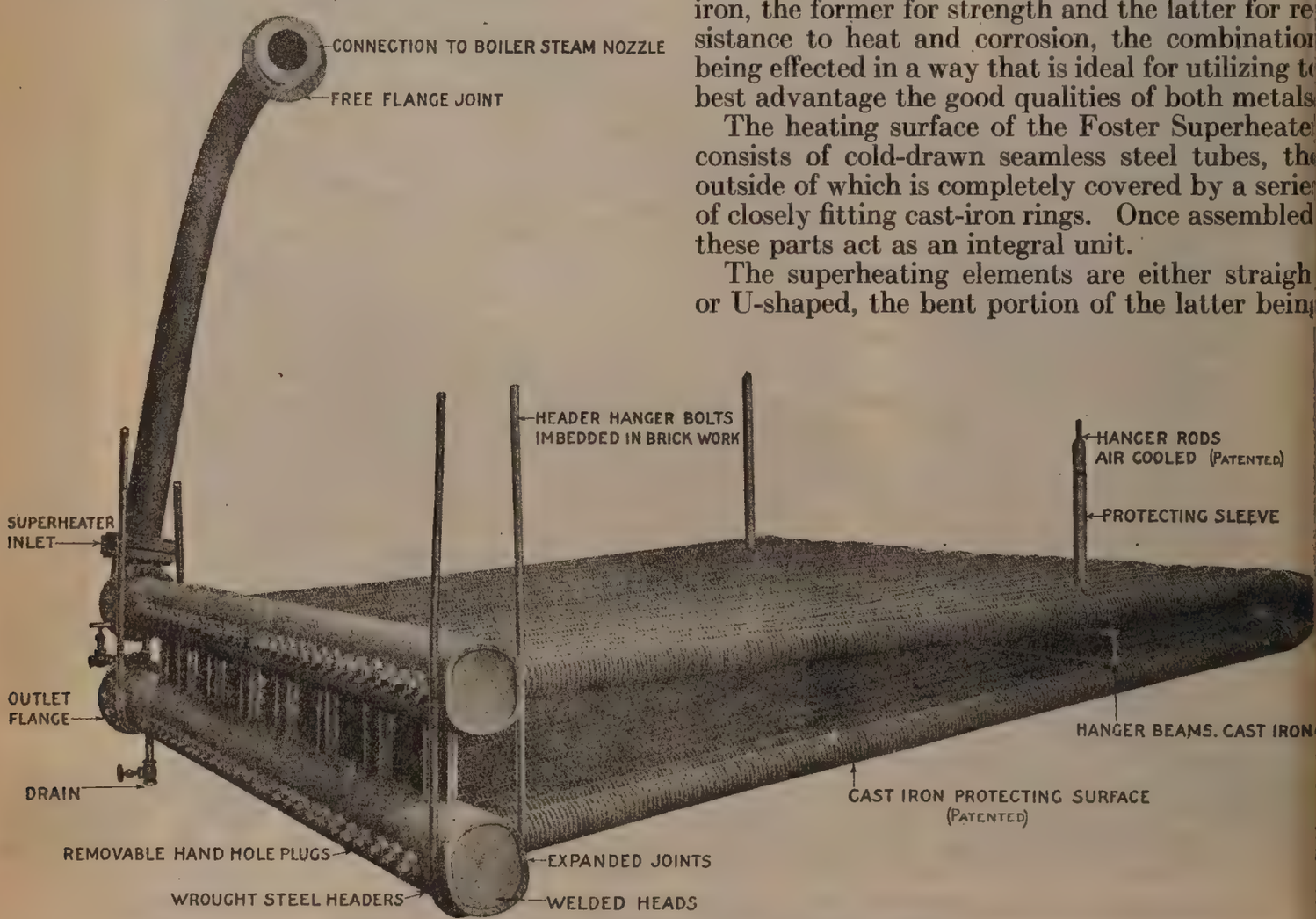
SIMPLICITY of design combined with maximum heat-absorbing qualities are prime essentials to successful superheater performance. The extended surface of the Foster Superheater accomplishes these results and is especially adaptable to the most difficult operating conditions. The advantages of this design must be evident from descriptions on the following pages.

An additional important consideration for year-in and year-out profitableness of a superheater installation is the reliability and durability of the parts, with accompanying low maintenanc and repair expense.

Cast-iron has given excellent results in producing durable superheaters, and has been extensively used because of its ability to withstanc high temperatures. Unfortunately, however, cas iron is not a sufficiently reliable material to mee the modern demands of high steam pressures. Th Foster construction employs both steel and cas iron, the former for strength and the latter for resistance to heat and corrosion, the combinatio being effected in a way that is ideal for utilizing t best advantage the good qualities of both metals

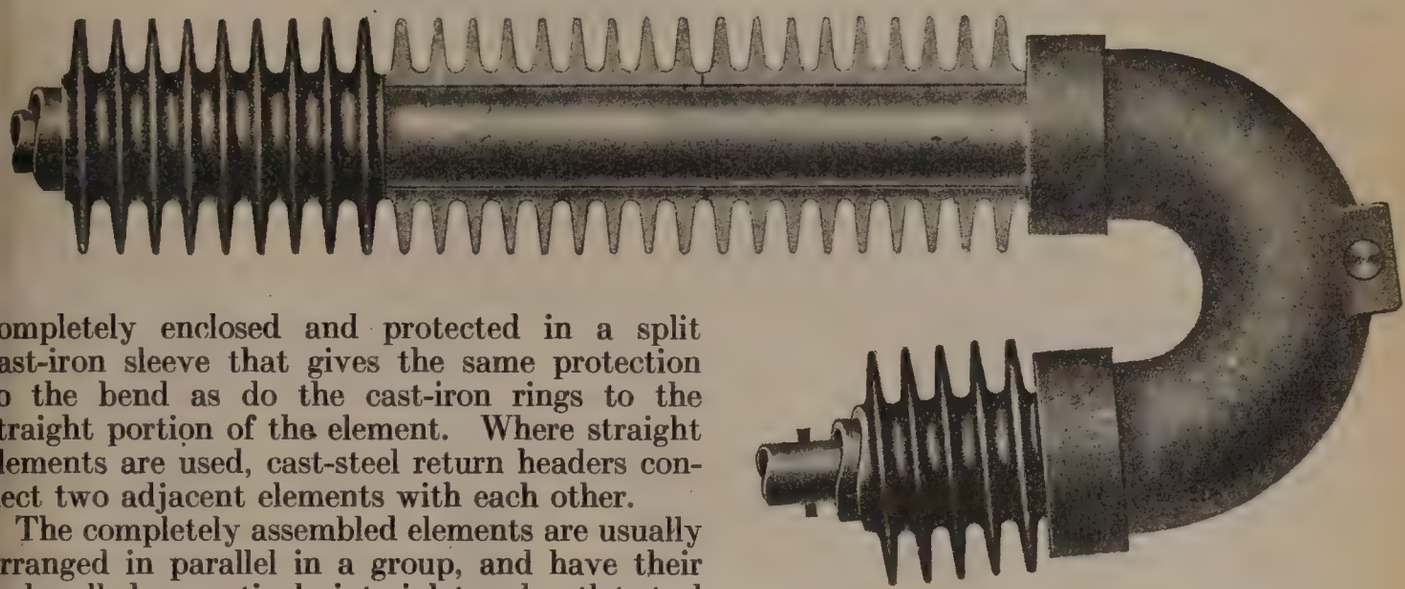
The heating surface of the Foster Superheate consists of cold-drawn seamless steel tubes, th outside of which is completely covered by a serie of closely fitting cast-iron rings. Once assembled these parts act as an integral unit.

The superheating elements are either straigh or U-shaped, the bent portion of the latter bein



Typical Foster Superheater and suspension for use in vertically baffled horizontal water-tube boilers

us cast-iron for durability.



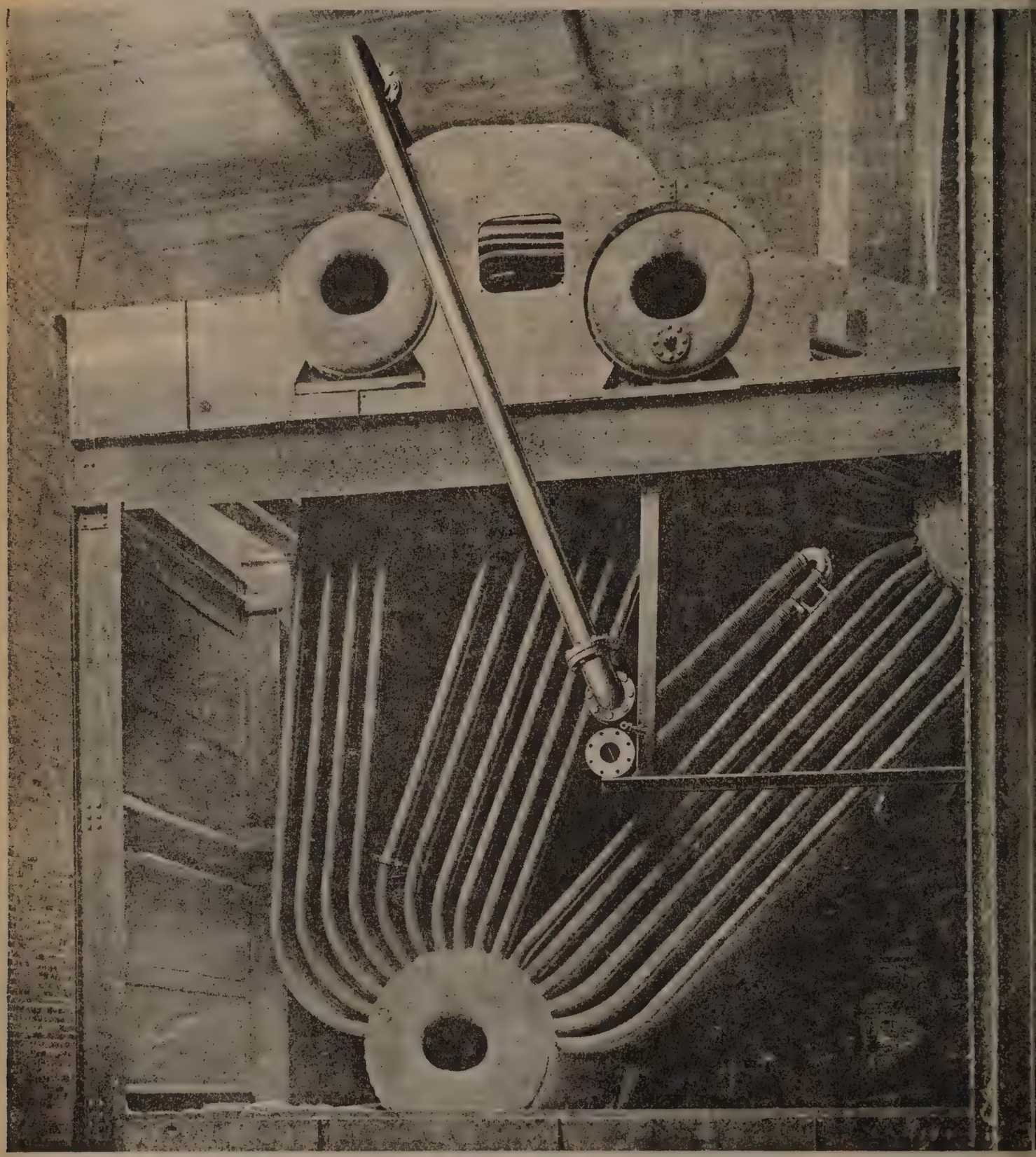
completely enclosed and protected in a split cast-iron sleeve that gives the same protection to the bend as do the cast-iron rings to the straight portion of the element. Where straight elements are used, cast-steel return headers connect two adjacent elements with each other.

The completely assembled elements are usually arranged in parallel in a group, and have their ends rolled respectively into inlet and outlet steel manifolds or connecting headers, one of which is

Typical installation of Foster Convection-Type Superheater in a Keeler Boiler

connected to the boiler outlet, the other to the outlet piping leading the steam to the main steam header. These manifolds or connecting headers are of forged steel with two flattened surfaces, in one of which are drilled holes into which the elements are expanded. Handhole plugs are fitted into the other to give direct access to the e panded joints. The handhole arrangement described on Page 23.

A fairly high degree of superheat can be o tained with a single deck of superheater element but where exceptionally high superheat is call



One of four Foster Superheaters in four 300-hp. Connelly Boilers at the plant of the Hibbing (Minn.) Water, Lig & Power Company. The superheating surface is located between the first and second banks of boiler tubes. T headers are supported by steel framework, which is in turn tied into the boiler framing. The superheater connectio are outside the boiler setting, and the inlet is connected to the boiler nozzle by a pipe bend

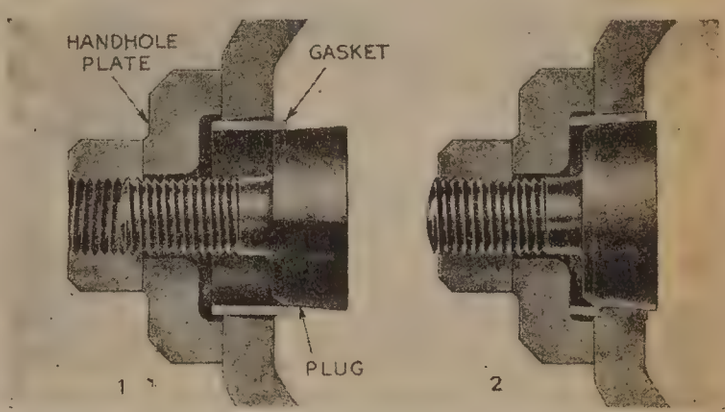
Foster Superheaters in five 500-hp. Goldie-McCulloch Boilers, St. Malo shops, Canadian Government Railways

or, the necessary surface can be obtained by double-decking (see Page 10) or by using a radiant-heat type superheater in series with the convection as shown on Page 36.

The Handholes and Plugs

THE tubes have rolled and flared connections with the headers, exactly the same as in standard boiler practice, and opposite each tube and a handhole provides easy access for interior inspection of the elements. Any element may be removed and renewed without disturbing the others, or any of the superheater piping connections.

The handhole plugs (see illustration) are turned from solid steel bars and are mushroom shaped. They fit neatly through the holes, and their bearing surfaces are slightly tapered. A gasket of copper or other metal is used between the plug and its seat in the header. This more than makes up for the slight difference in size between the plug and the hole, so that, with the gasket in place, the



Handhole plug of Foster Superheater before and after tightening. Position 1: Plug and gasket inserted in header. Position 2: Plug drawn into place and gasket forced against header by tightening the nut

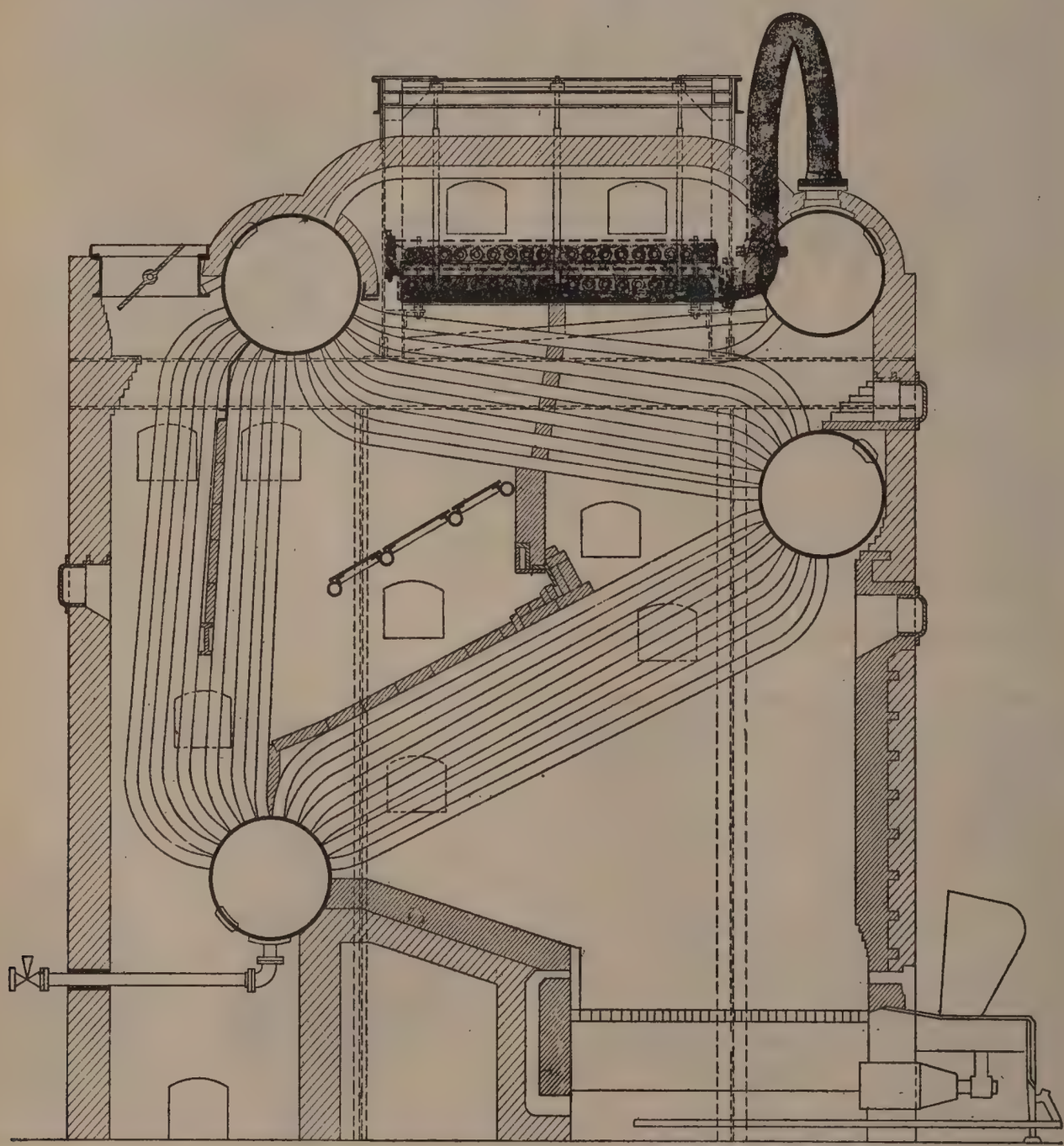
plug cannot be pulled out through the hole.

A handhole is opened by removing the nut and plate and knocking the plug into the header. A wire or string previously attached to the plug makes it easy to get back.

The copper gasket can be used many times without renewing, and even when badly scarred can frequently be used again if annealed and smoothed over. The plug, being tapered, is driven tighter into the hole when pressure is raised in the superheater.

Drains

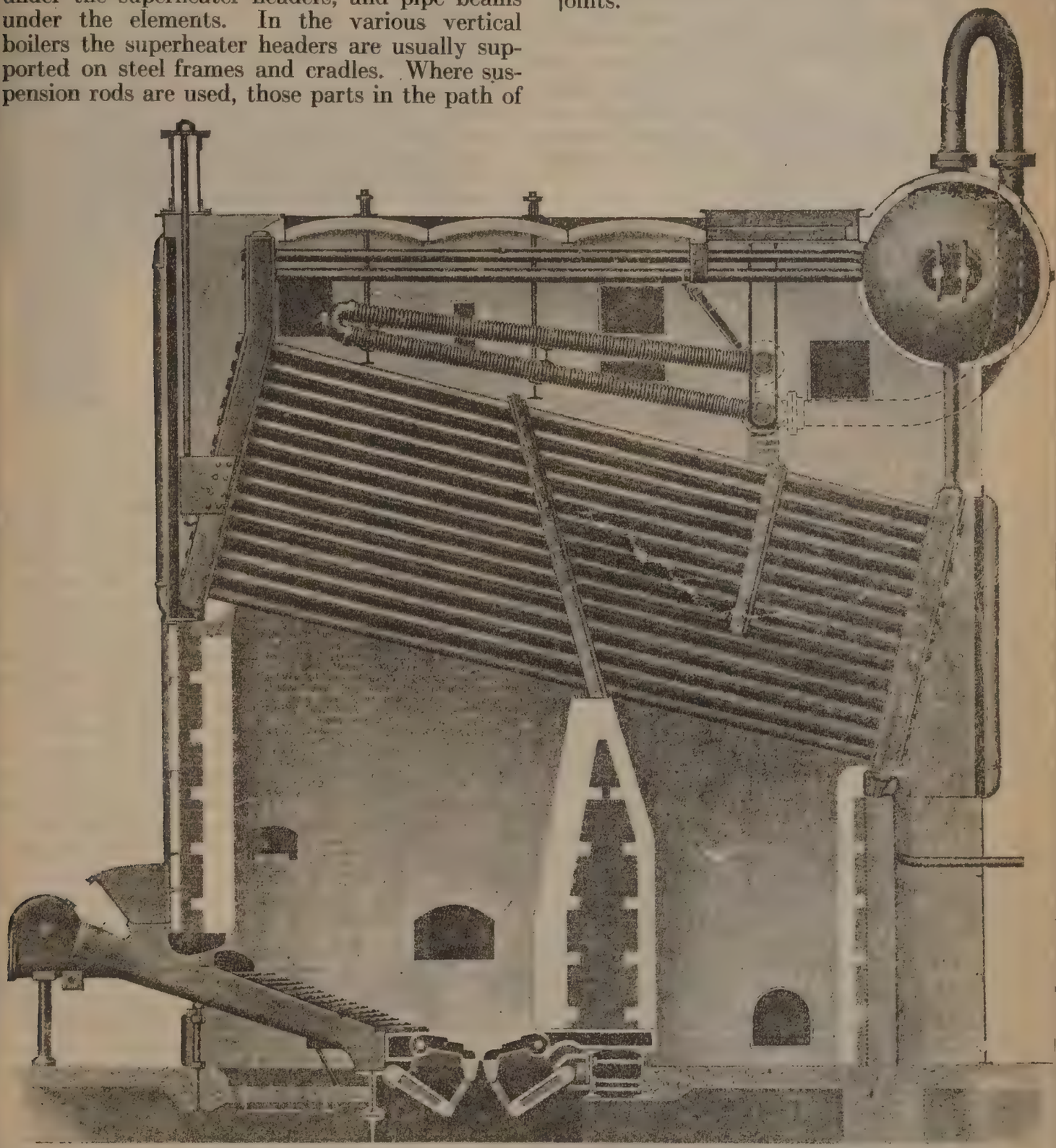
ALL Foster Superheaters are provided with drains. To remove any water of condensation that may collect in the heating surface during periods when the superheater is inactive, the drain should always be open before starting the boiler so as to make sure that any such collection of moisture in the superheater may not be carried over into the pipe line by the steam passing through the superheater. Drains are also used to prevent damage to superheaters through the freezing of any water which might be in them during periods of disuse. Drains should be open for this reason as soon as pressure is off the boilers and before cooling.



Typical arrangement of Foster Superheater in the Kidwell Boiler. The superheating elements rest in a horizontal position, crosswise of the boiler, and project through the side wall to headers, which are outside the setting. The superheater is supported from overhead steel framework by means of air-cooled U-bolts and is connected to the boiler outlet nozzle by pipe bend

Support for the Superheater

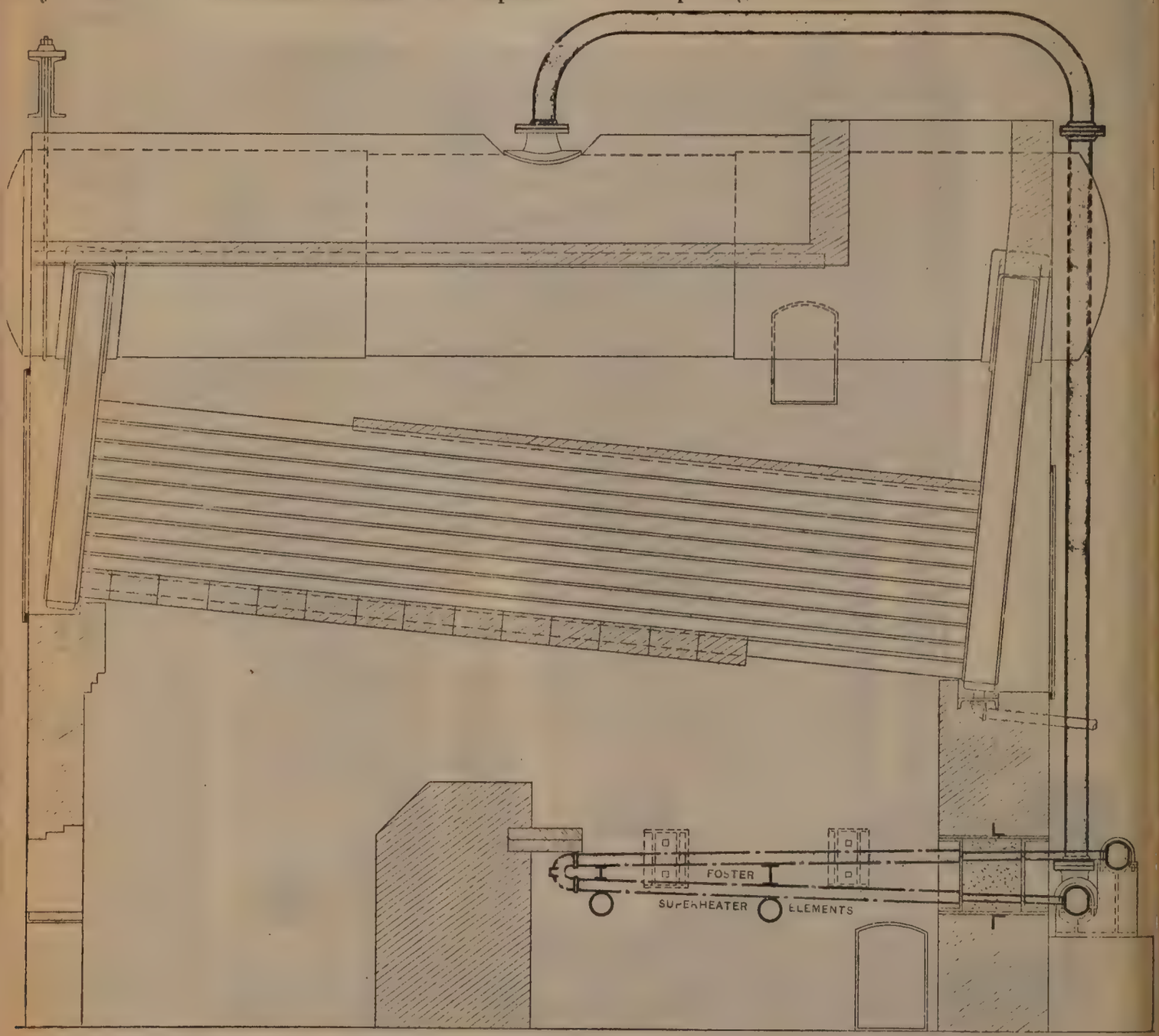
THE support for the superheater depends upon the type of boiler. In horizontal water-tube boilers the superheater is suspended by air-cooled rods attached to overhead beams supported on the boiler drums or the top of the setting, or by cradles under the superheater headers, and pipe beams under the elements. In the various vertical boilers the superheater headers are usually supported on steel frames and cradles. Where suspension rods are used, those parts in the path of the hot gases are protected by pipe sleeves. Th superheater is independent of the brick structu and free to expand without straining any part The conn...ng headers and their connections a located outside the active path of the hot gas and away from th. greatest heat, and are place for easy access to handhole plugs and expand joints.



Foster Superheater in Walsh & Weidner Cross-drum Boiler. The position of the superheater with reference to tub and baffles is practically the same as for longitudinal-drum boilers, as shown on Pages 3, 5, 11, 15, 21 and 23. Th headers are suspended by U-bolts from overhead structural beams resting upon the side walls of the setting. The el ments rest upon cast-iron beams, also suspended from overhead structural members. A similar arrangement is used Babcock & Wilcox, Connelly, Springfield, Casey-Hedges, Keeler, International, Heine, Wickes, and Goldie & McCu loch cross-drum boilers

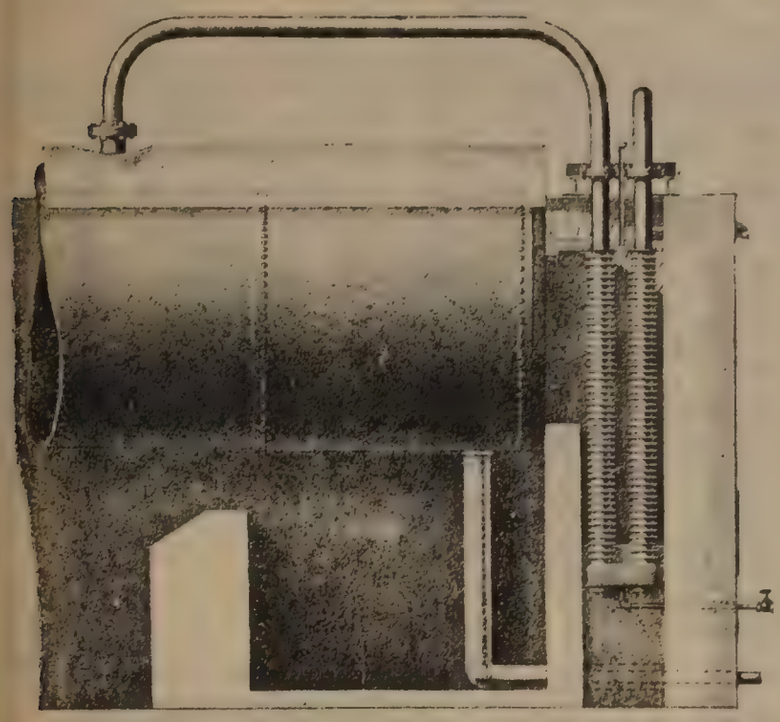
Installation of Foster Superheater and Heating Surface

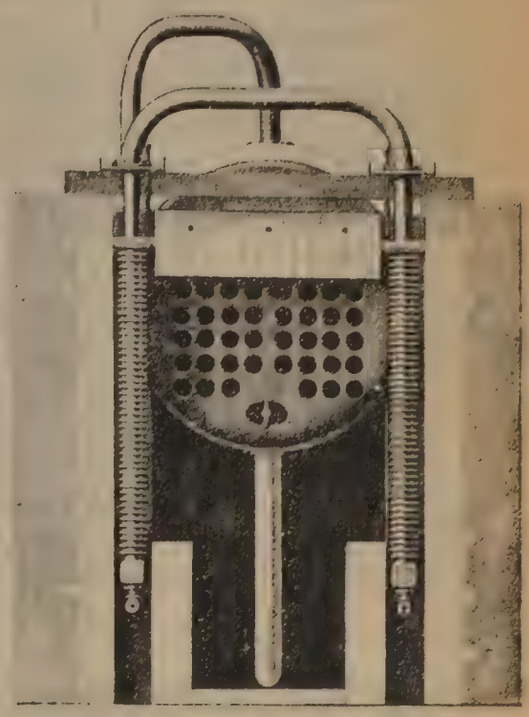
FOSTER Superheaters of all types are usually shipped knocked down. The various parts of the superheater are assembled within the boiler setting, the elements being expanded into the connecting headers, after which the handhole plugs, giving access to their expanded joints, are put in place and tightened up. Wherever possible, it is to the customer's advantage to have this work supervised by one of our erecting engineers, who are thoroughly familiar with our construction and able to see that the work is properly done. All work done under our supervision is tested with hydraulic pressure at least 50 per cent in excess of the steam pressure to be carried, and proven tight before our engineer leaves the job. Complete operating instructions, etc., are always furnished with our superheaters for the use of the operating force. The work of installation is simple and requires only a short time to complete. The placing of superheaters in existing boilers does not require any serious brickwork changes, as the superheater parts can be passed into the boiler setting through a side opening and assembled within.



A variation of the arrangement of Foster Superheater from that shown on Page 9 for horizontally baffled horizontal boilers. In this instance the position of the superheater is reversed. The inlet and outlet headers are located at the rear and outside the setting wall and supported by pedestals from the floor. The superheater elements pass through cast-iron plates in the rear boiler wall and are supported within the setting by means of air-cooled pipe supports. This rig is used where three or more boilers are set in battery, and may also be used with single boilers. It is applicable to all makes of boilers listed in the caption for illustration on Page 9

Foster Superheater for Horizontal Return-tubular Boiler





Foster Superheater with 4-in. elements in a horizontal return-tubular boiler

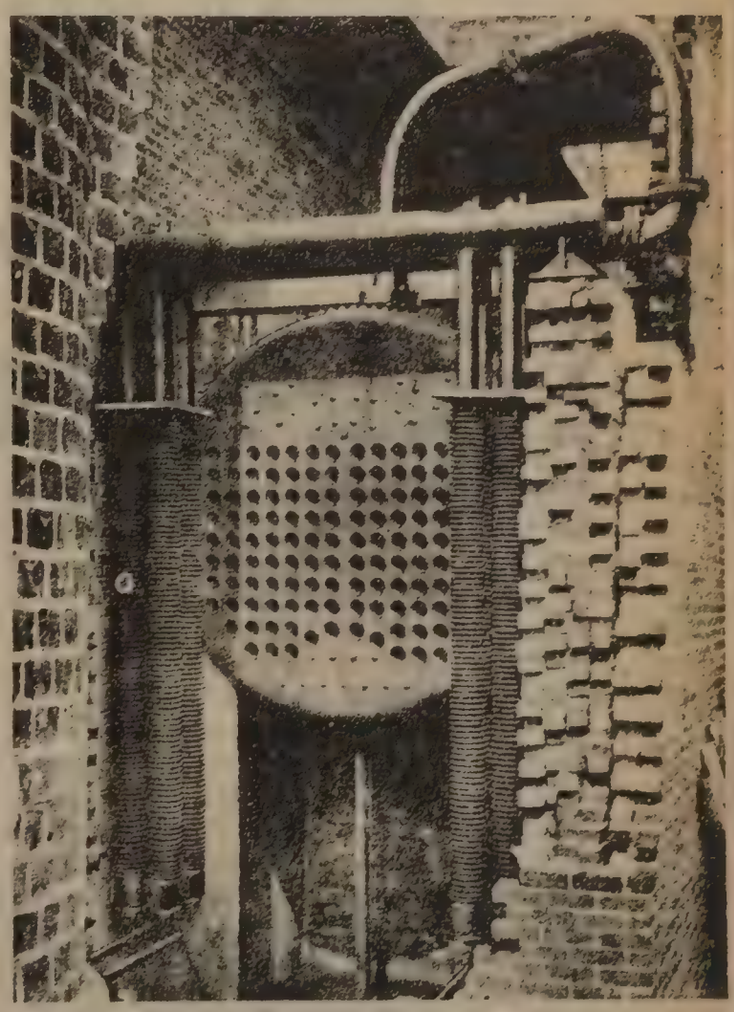
BOILERS of this general type are so much alike that two general types of Foster Superheaters meet almost all conditions. The choice of one or the other of these is based on space limitations and boiler construction rather than on boiler size. In a few instances special design may prove more desirable than standard, in which cases the flexibility of application of Foster Extended Surface is a great advantage.

The superheater is usually placed in the rear combustion chamber. The pictures show applications of the type having 4-inch Foster Superheating Elements, with inlet and outlet headers at the top, resting upon cradles on the boiler setting.

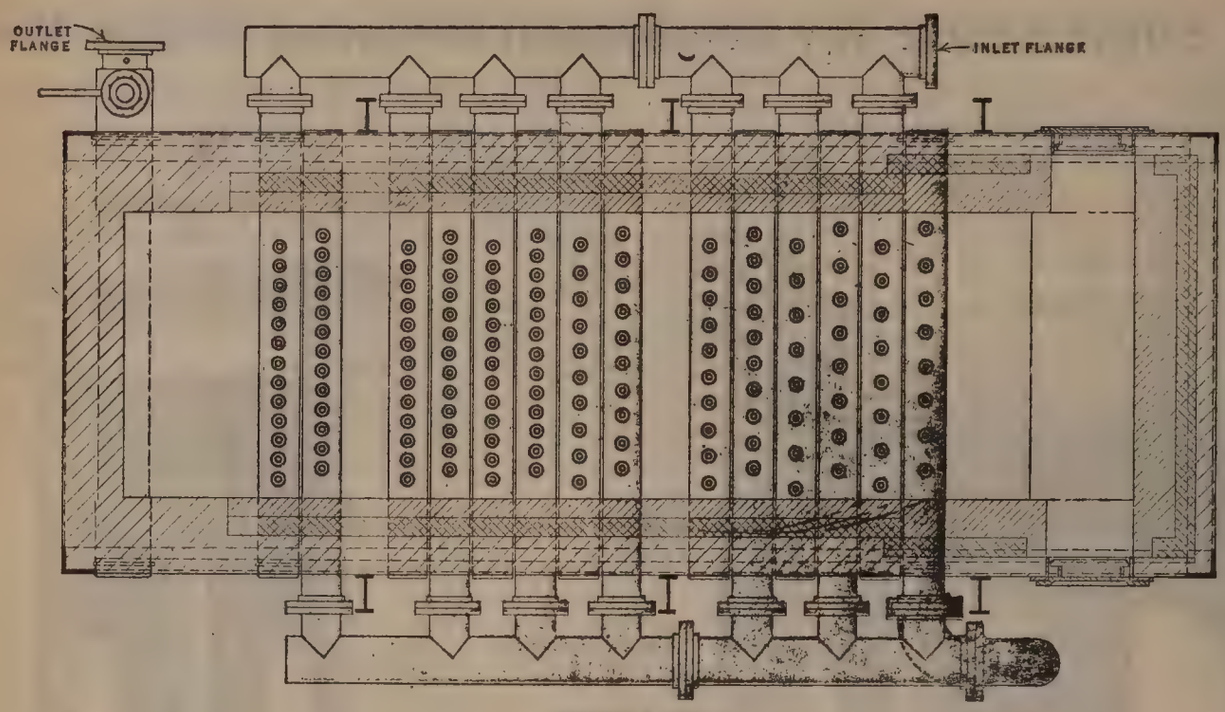
The manner in which the saturated steam from the boiler is piped to the superheater inlet and in which the superheated steam leaves through the superheater outlet is clearly shown.

The other standard type Foster Superheater for horizontal return-tubular boilers has its headers horizontally placed within the rear combustion chamber, with 2-inch inverted U-shaped elements extending upward. The headers are suspended from the inlet and outlet pipes, which are formed into Foster Heating Surface inside the chamber and pass up through the arch to the outside connections.

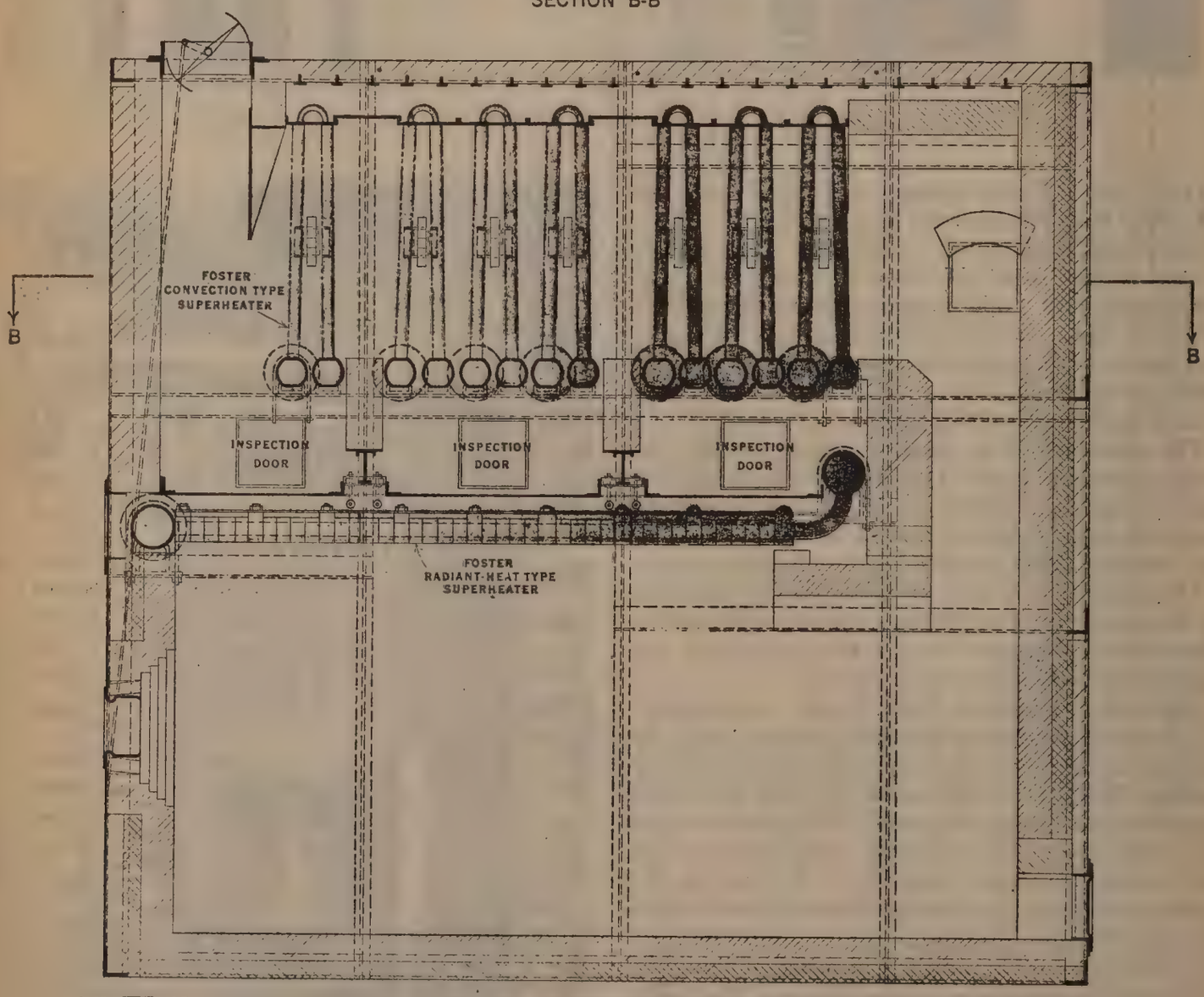
Both types have drains for removal of moisture which may accumulate on shutdown of the boiler or from other causes. Both also have all expanded joints out of the path of the hot gases and readily accessible for inspection and repair.



Typical Foster Superheater installation in a horizontal return-tubular boiler

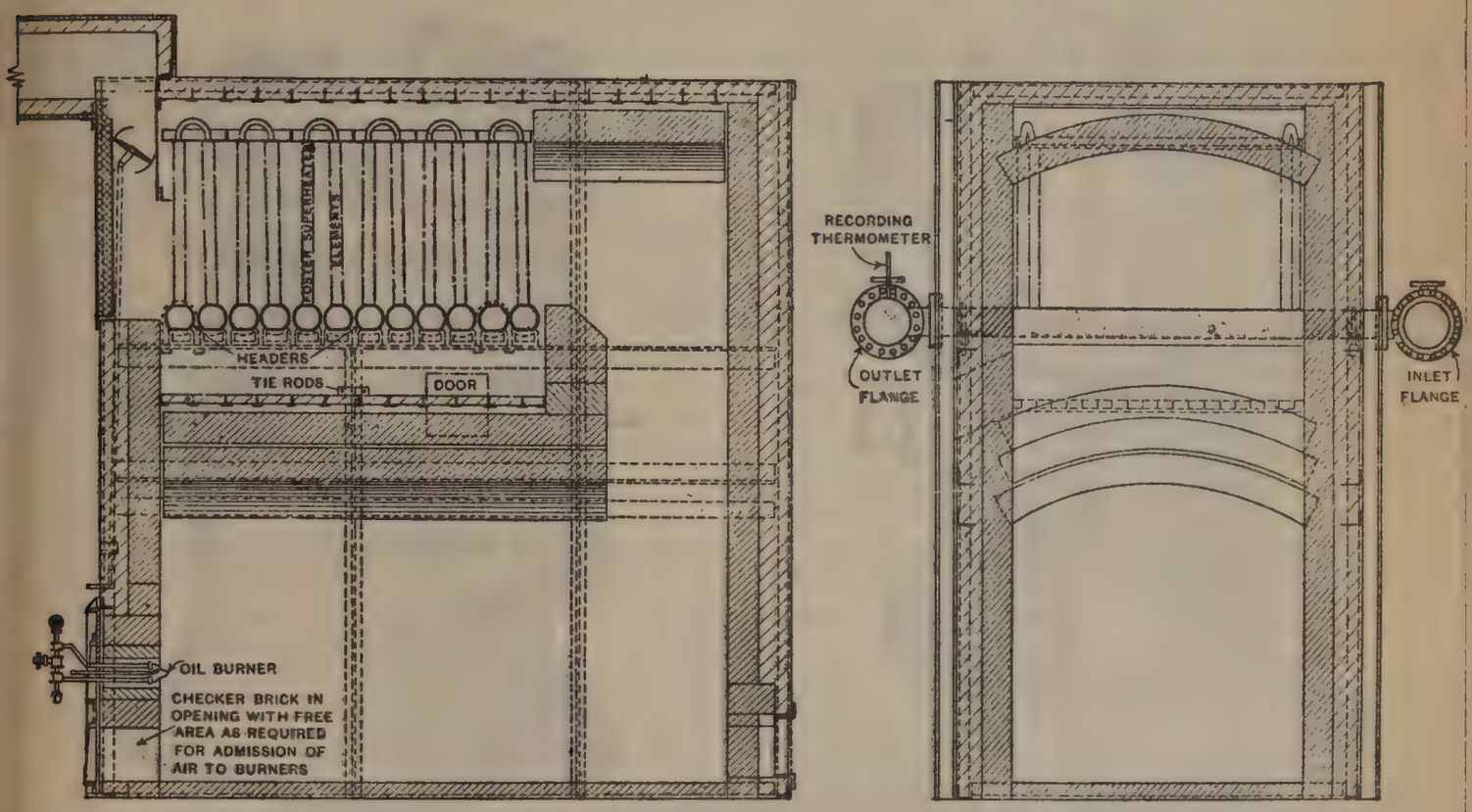


SECTION B-B



Foster Direct-fired Two-stage Superheater with Foster Convection-type Heating Surface as first stage and Foster Radiant-Heat Surface as second stage. The use of the Radiant-Heat Superheater as a roof for the combustion chamber provides for the combustion of fuel at high furnace efficiency.

Foster Direct-fired Superheaters



Foster Direct-fired Superheater with superimposed heating surface (See opposite page)

THE direct-fired superheater, placed in a separate brick setting with individual furnace, utilizes coal, oil, gas, bagasse or other fuel, including waste gases, and may be used to produce any final temperature up to 1000 deg. fahr. It finds application in boiler plants and for industrial uses where the following conditions exist:

First: Where space limitations prevent installation within the boiler, including application where very high degrees of superheat are desired.

Second: Where only part of the steam is to be superheated.

Third: For waste heat utilization, as in steel plants, forges, oil refineries, chemical works, etc.

The heating surface is usually of the U-bend type, with the elements set vertically so as to be self-supporting, and the headers at the bottom to provide drainage, or with elements horizontal and having near their ends cast-iron plates which build up into a wall that keeps the joints outside the path of the hot gases.

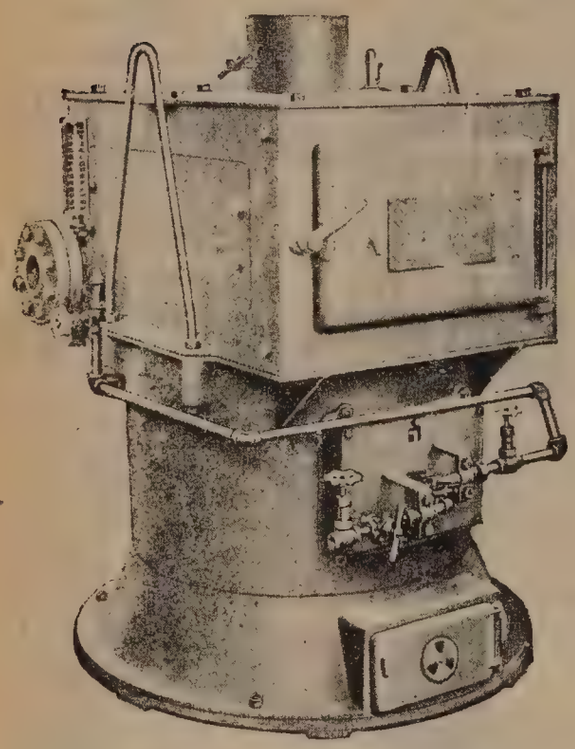
The most satisfactory arrangement of furnace setting is shown above, although this may be considerably varied to meet local conditions. The heating surface is arranged so that the steam passes counter-current to the gases of combustion, in this way obtaining maximum efficiency.

Foster Direct-fired Superheaters are made in standard sizes for various capacities and degrees of superheat, and may be designed for any special capacity, space requirements or other conditions of operation.

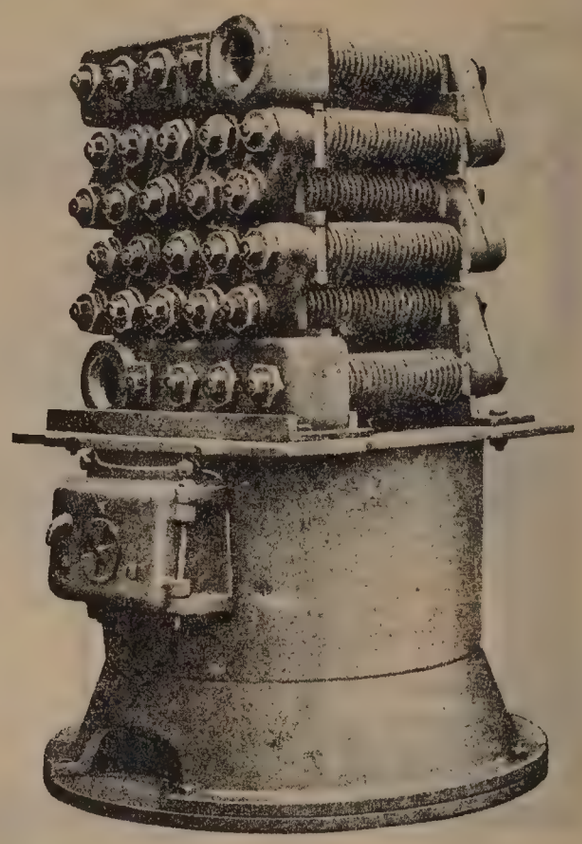
Foster Radiant Heat Surface in Direct-fired Superheaters

THE advantages of the Foster Radiant-Heat Superheating Element outlined on Page 35 have special reference to superheaters attached to individual boilers. This form of superheater surface applies to even greater extent when used in connection with direct-fired superheaters, and the first development of this kind was made in this connection. Because of the impossibility of carrying in a direct-fired superheater, furnace temperatures as high as in boilers, due to the destructive effect of radiant heat on the front rows of such superheater elements, the fuel efficiency of direct-fired superheaters has heretofore been much less than obtainable under good firing conditions in the boiler. The use of Radiant-Heat Elements forming the roof of the combustion chamber of superheaters of this type, has made it possible to build such units so that the overall efficiency approaches that of a boiler, and in the case of large units of this type makes possible the use of automatic stokers to replace hand firing. A typical combination of Foster Radiant-Heat and Convection types of Superheater in a direct-fired unit is shown on Page 28.

Foster Portable Superheaters



Foster Gas-fired Portable Superheater with 48 lineal feet of element



Foster Coal-fired Portable Superheater with 72 feet of superheating element. Top casing removed to show arrangement of heating surface

THE Foster Portable Superheater meets the needs of the manufacturer and chemist in working out new processes. It combines the advantage of compactness and portability with ease of operation and rugged construction, and is shipped from our plant complete in every detail. The only work required to put this superheater into operation is to connect up the steam line to the inlet and outlet flanges and to place the small stack or connect to an existing breeching for carrying off the waste gases of combustion.

The heating surface is located immediately above the fire box. Steam enters at the top of the superheater and passes down to the outlet in counter current to the gases of combustion as the latter pass over the heating surface. The combustion chamber may be equipped for burning coal, oil or gas. The elements or tubes are expanded into steel connecting headers and cast steel return headers with handhole plugs are provided opposite every expanded joint, thus giving direct access to every expanded joint in the superheater. Inspection doors in the superheater casing and located at both ends of the elements give access to all the handhole plugs from the outside of the superheater.

This form of superheater is built in three standard sizes, as listed in the table. These superheaters are of course suitable for adding considerably more than 200 deg. superheat to the steam. If twice the superheat called for by the table is required, the amount of steam that can be superheated would be half that given for the lower superheat.

Standard Sizes of Foster Direct-fired Portable Superheaters

Size	Weight	Width	Height	Steam pipe	Smoke pipe	Air heating capacity in cubic feet per minute		Steam superheating capacity in lb. per hour at 100 lb. gauge	
						60 to 160 deg. fahr.	60 to 260 deg. fahr.	100 deg. Superheat	200 deg. Superheat
16	1950 lb.	2 ft. 9 in.	3 ft. 9 in.	3 in.	7 in.	660	325	700	380
48	3860 lb.	3 ft. 8 in.	5 ft. 0 in.	4 in.	10 in.	2000	950	2100	1140
72	1720 lb.	3 ft. 8 in.	5 ft. 7 in.	4 in.	10 in.	3000	1400	3150	1710

The Foster Radiant-Heat Superheater

DURING recent years the development of the boiler unit has been very rapid and present operating conditions call for considerable revision in the design of the superheater to meet modern specifications.

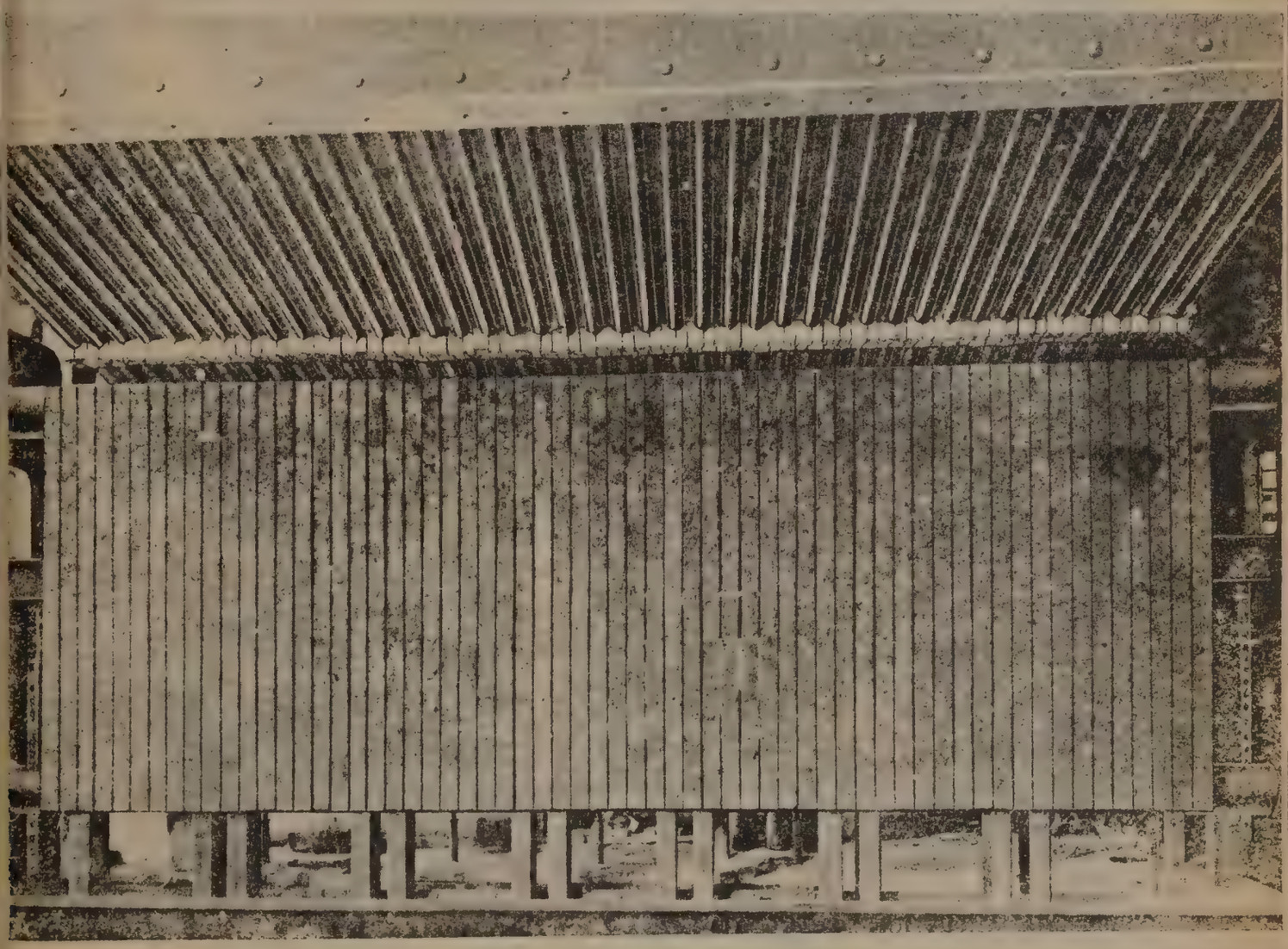
Probably the greatest change is found in the design of the furnace and in the heavy overload operation. The boiler is now set high above the floor line so as to provide very large furnace volume and provision is made for burning fuel not only at a high rate but with a very close control of the air supply so as to get perfect combustion.

This practice results in high furnace temperatures, and large areas of furnace wall exposed to severe heat.

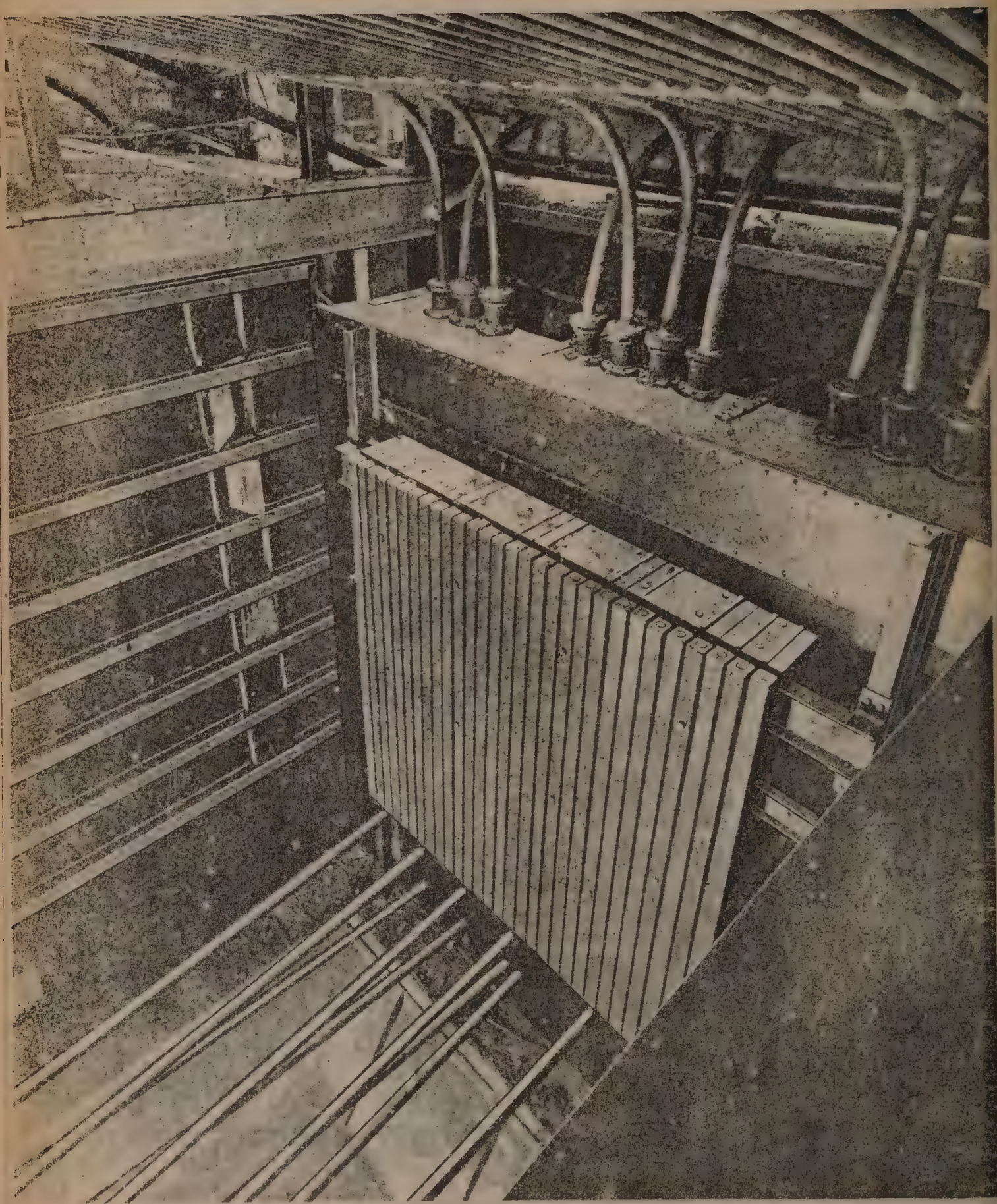
A further result of the close control of air supply is a reduction in the gas volume and a consequent decrease in the heat available for convection type superheaters located either within or above the main tube bank of the boiler.

The problem so far as the superheater design is concerned has been further affected by the tendency to higher steam pressures and higher superheat. In central power plant practice, pressures of 350 to 400 lb. gauge are now common and a final steam temperature of 700 deg. fahr. in combination with this pressure is often called for

Such specifications make the use of convection superheaters placed in normal available locations in the boiler very difficult if not impossible. Additional space in the boiler has to be provided for such superheaters and this often requires changes in boiler design and these changes are apt to have a marked effect upon the baffling arrangement, not always desirable from the standpoint of overall efficiency and maintenance.



Foster Radiant-Heat Type Superheater which comprises the second or high-temperature stage of the Foster Two-stage Superheater in a 1875-hp. Babcock & Wilcox Cross-drum Boiler at the Hi-Bridge Station of Northern States Power Co., St. Paul, Minn. The first stage (not shown) consists of a Foster Single-deck Convection Type Superheater above the tube banks. Eight of these boiler units are Foster-equipped in the same way in this plant, the superheater arrangement in each being similar to that shown on Page 36



Radiant-Heat or high-temperature stage of Foster Combination Radiant-Heat and Convection Type Superheater in 1011-hp. Heine Boiler. Located in rear wall of setting. Photo taken at the plant of St. Paul (Minn.) Gas Light Co., where three boilers of same make and size are Foster-equipped in the same way. The general superheater arrangement is shown on Page 36

These operating conditions also have another effect upon superheater design not always appreciated. Turbine designers generally limit the final steam temperature that may safely be used in such units. In order to obtain the maximum efficiency, the superheater specification often calls for a temperature very close to the limiting temperature for which the turbine is designed—that is to say, the factor of safety between the operating steam temperature and the highest temperature that can be used, is small.

The temperature obtained from a given superheater of the convection type is affected by the load on the boiler and by the gas volume or percentage of CO_2. The characteristic of all convection-type superheaters is to show a rising tendency in the superheat obtained with a rising load, this being influenced at the higher ratings by the percentage of moisture contained in the steam delivered to the superheater, which may offset the tendency to rise. The closeness of the control of the air supply to the furnace affects the gas volume and therefore a decrease in furnace efficiency or a falling off in CO_2 will result in a rising tendency in the superheat obtained.

Where boilers are designed for heavy overload operation close attention should be paid to these factors, especially where the superheaters are designed for a final temperature close to the danger point from the turbine operating standpoint.

This company has been fully aware of these tendencies and some years ago took steps to produce a type of superheater that would meet these conditions. The result was the development of the Foster Radiant-Heat Type Superheater, where the heating surface is placed in one or more of the walls of the combustion chamber. This surface absorbs heat directly by radiation from the burning fuel and from the heated brick walls of the furnace. The superheater is removed from the boiler heating surface and allows the latter to be designed and baffled for the most efficient absorption of heat from the gases. This is a distinct advantage in the design of the boiler proper.

The high final steam temperatures called for by many specifications has led to the development of an all-steel construction for the heating surface and to fill such specifications, we are now using elements of heavy rectangular steel sections assembled so as to form a flat metal wall in one or more of the walls of the boiler furnace. This construction is clearly shown in the sectional view.

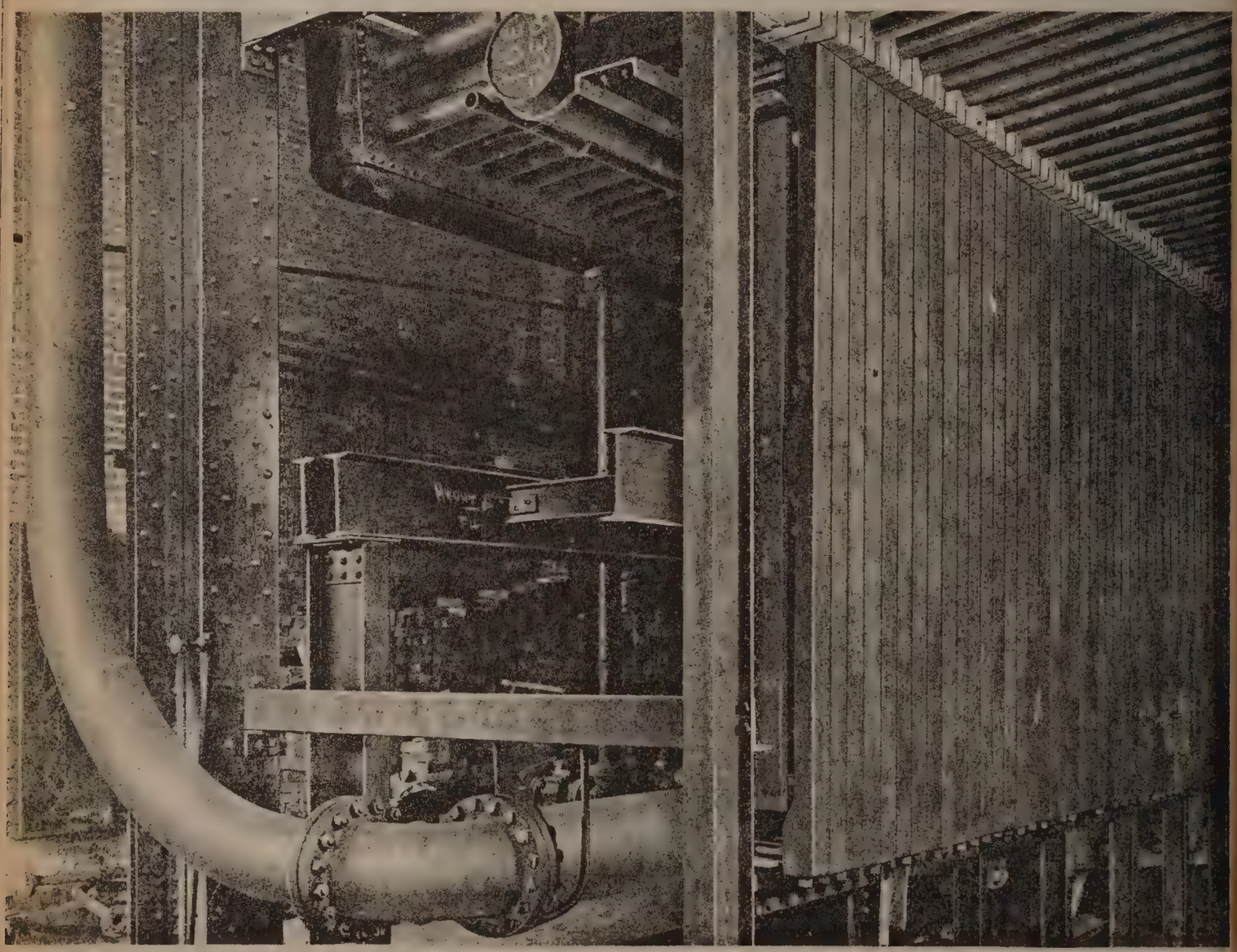
Referring also to illustrations on Pages 31 to 36, it will be noted that these steel elements are assembled so that each element is connected at each end to inlet and outlet forged steel manifolds or headers placed outside of the wall of which the elements form the inside face. Heavy steel nipples are used for this purpose, these being expanded into elements and manifolds, with handhole plugs placed in manifolds opposite each nipple, so as to give access to the joint and the interior of the nipple for inspection.

Either horizontally or vertically arranged elements are used. The elements are supported and held against transverse movement by stiff backing frames, the connection being such that the elements are free to expand longitudinally. The connecting headers are supported by this frame, but are free to move by the expansion of the superheater elements, so that there is no strain on the connecting joints. Sheet steel plates are fitted to the structural steel, forming a substantial and ornamental casing for that portion of the furnace wall. The space between the steel casing and the elements is filled with insulating material. The supporting lugs of the elements are held by bolts, which are accessible from the outside of the casing so that any element can be taken out and replaced without disturbing the insulation or backing.

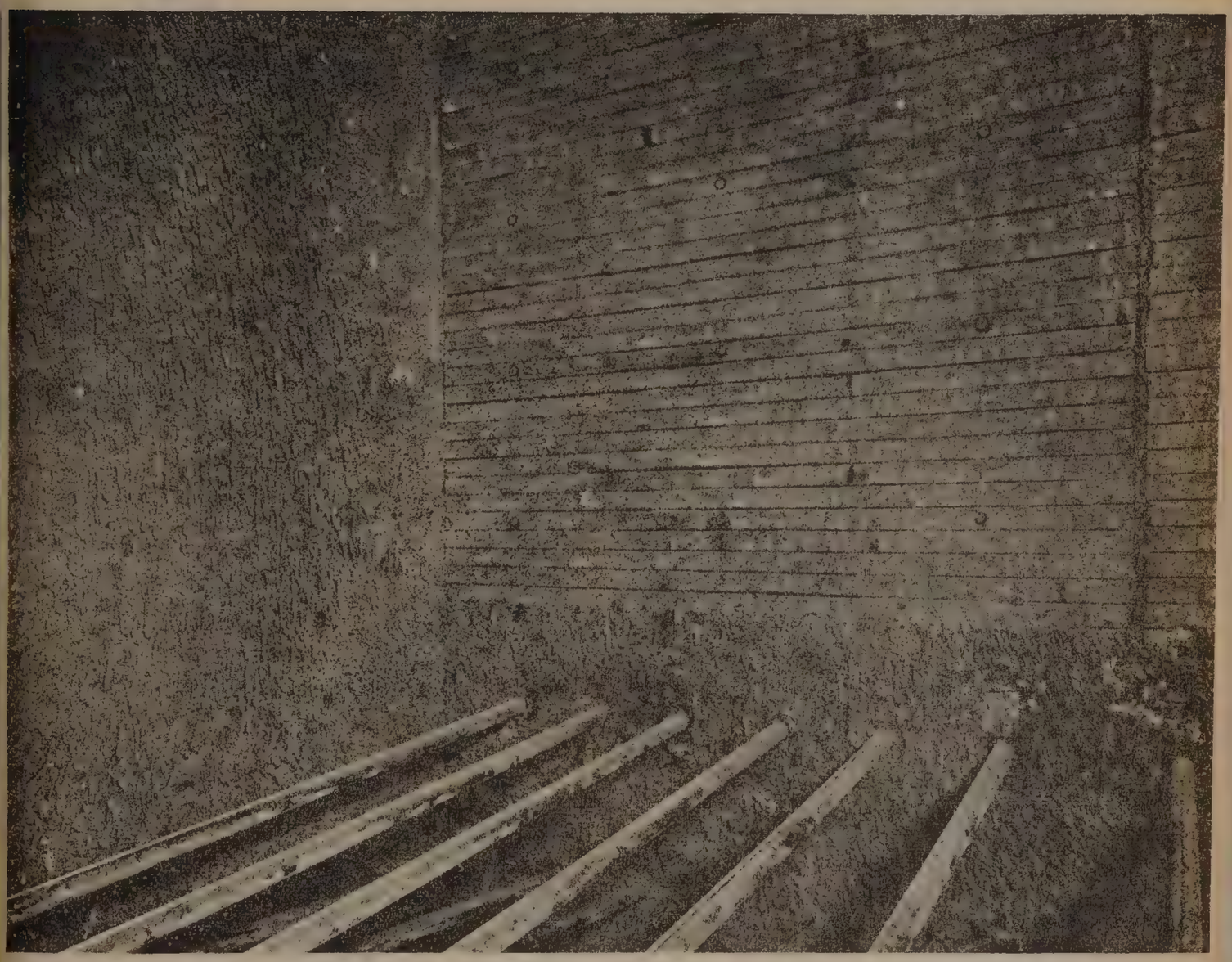
There is little tendency for incrustation or furnace dust deposit to

Typical vertical element of Radiant-Heat Superheater

take place on the face of the elements of the superheater. However, a dust deposit that is ordinarily not objectionable, if allowed to accumulate would gradually reduce the superheat. For this reason, the radiant heat superheater is fitted with a soot-blowing device that not only serves as a means of keeping the face of the superheater clean, but also gives a practical way of controlling the superheat that has heretofore not existed. Certain elements of the superheater are fitted with hollow staybolts, the ends of which are flush with the face of the element, and into which are screwed soot blower nozzles made of heat-resisting metal. At the other ends a steam pipe is connected. The ends of these nozzles are blank but a series of holes is provided around the circumference, with the result that when steam is turned on, a series of radial steam jets issues in a plane parallel with the face of the superheater, and at a distance of about ¼ in. from the superheater. These jets sweep the surface of the superheater absolutely clean for a radius of 2 ft. to 3 ft. The nozzles are, therefore located over the face of the superheater at a distance of about 4 ft. vertically and horizontally. There are generally from three to five rows of these soot blower nozzles, each row being connected up and controlled by one steam valve. Under operating conditions, one row is blown at a time, and it is seldom that more than two rows are blown in any one day. These rows are taken in rotation, so that the superheater is dusted over its entire surface about once in every two and one-half days. The blowers need not be kept on more than one minute at a time. If all the blowers were used once in every twelve hours, there would be an increase of superheat which usually amounts to about 50 deg., so that, as before mentioned, the soot blowers permit an adjustment of superheat over a range of 75 deg. or 100 deg. The simplicity, thoroughness and reliability of this method of cleaning is one of the desirable features of the Foster Radiant-Heat Type Superheater.



Foster Radiant-Heat Superheater in 1013-hp. Edge Moor Boiler. One of two similar installations at the plant of Metropolitan Edison Co., West Reading, Pa.



Foster Radiant-Heat Type Superheater in a 1765-hp. Edge Moor Boiler. Note the rosette type soot blowers on surfac (described on Page 34) and the cleanliness of the superheater surface in comparison with the brickwork, and see text f description of the soot blowers. This installation is one of eight similar in the Lakeside Station of the Milwaukee (Wis Electric Railway and Light Co.

Advantages of Radiant-Heat Type of Superheater

THE obvious advantage of the Foster Radiant-Heat Superheating Element is that it utilizes efficiently, radiant heat that is often the cause of high maintenance costs for furnace brickwork. In doing so the heater itself replaces a part of the furnace walls, and the cost of brickwork thus saved may properly be considered an amount that should be credited to the cost of superheater installation.

Additional advantages are:

First: It is absolutely independent of boiler and will not interfere in any way, with any design or system of baffling that may be wanted by boiler builder or operator.

Second: A high degree of superheat can be obtained in a limited space; this due to high rates of heat transfer by radiation.

Third: The superheater is accessible from a sides, easy to inspect and easy to repair.

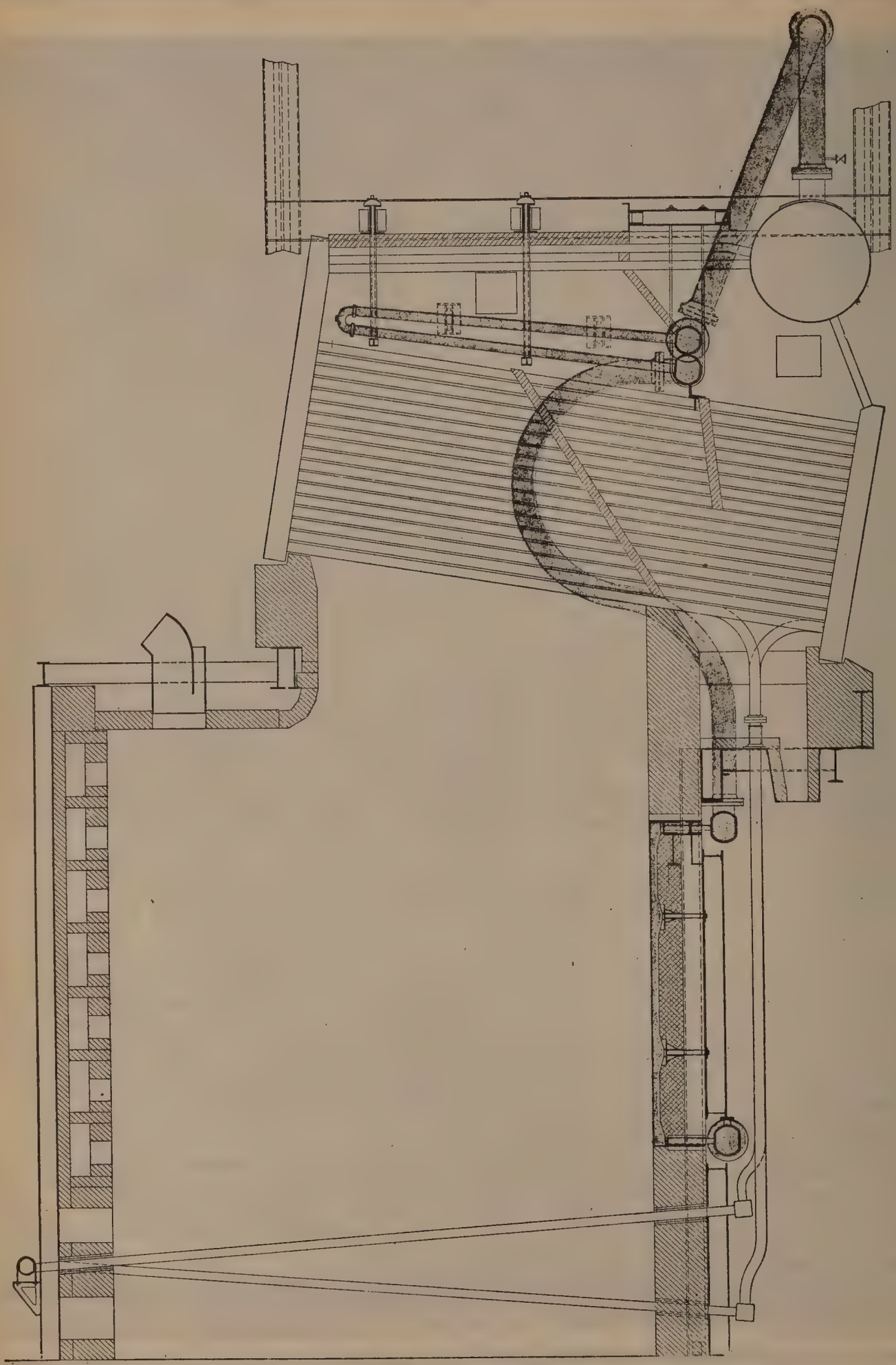
Fourth: No addition to draft loss through th boiler is offered by this construction.

Fifth: Pressure loss is low as the length of trav through the superheater is reduced, with few turns and bends than are necessary in oth superheater constructions.

Sixth: Maximum superheat is obtainab throughout the economical ranges of load witho the same tendency for rise in temperature und peak-load operation, thus higher average supe heat is available during total time of operatio

Effect of Radiant-Heat Superheate in Protecting the Brickwork

THE radiant-heat superheater may be giv credit for further usefulness in the mode



Combination Foster Convection and Radiant-Heat Superheaters as installed in Heine Boilers with pulverized fuel furnaces at the plant of the St. Paul Gas Light Company at St. Paul, Minn.

boiler unit from the standpoint of furnace brickwork protection. The very high furnace temperatures now employed due to close air control and high load operations, have made it increasingly difficult to maintain the brickwork structure. The Foster Radiant-Heat Superheater, by replacing at east a part of the brickwork, aids materially in the protection of the remaining brickwork and viewed from this standpoint alone, is very much worth while.

Flexibility of Design and Operation

THE Foster Radiant-Heat Superheater can be applied to any type of water-tube boiler and has special value when installed in large-size water-tube boilers set high with large combustion chambers arranged for operation at high overload ratings.

In such cases the elimination of draft restriction and the ability to baffle the boiler without considering the superheater, is of very great importance. The success of the rosette type soot blowers which enable the surface to be cleaned in whole or in part so as to maintain a constant steam temperature regardless of rating or furnace efficiency, is marked, and affords a flexibility in superheater operation not possible with other types.

The Foster Radiant-Heat Superheater is offered as a construction that has already proved its value and is backed by the reputation that all Foster products have for quality and service.

Combination Radiant-Heat and Convection Superheater

PARTICULAR mention should be made of the use of the radiant-heat type of superheater in combination with the convection type superheater. On Page 36 is shown a typical arrangement of this kind in a horizontal water-tube boiler. Steam passes from the boiler to the inlet connecting header of the convection stage of the superheater, through this part of the heating surface and thence by an outside pipe connection to the inlet header of the radiant-heat type superheater, then through this heating surface to another connecting header, from which piping connects to the steam main.

This combination of the two types of superheater offers great possibilities for design so as to obtain a flat curve of superheat over a wide range of loads. The general practice is to install a convection-stage superheater of the single-loop type, thereby obtaining from 100 to 150 deg. of superheat in this stage of the superheater. The further rise of temperature desired is then obtained in the second or radiant-heat stage.

The single-loop type of superheater can be installed in practically all of the standard types of water-tube boilers without any material change to the boiler design and can be located at a point in the boiler where gas temperatures best suited for this type of heating surface are obtained. The additional radiant-heat-absorbing surface required will be less than if all the work were done by this type of heating surface, and, therefore, the space required in the wall or walls of the furnace is less than if the superheater were entirely of the radiant-heat type.

As already pointed out, the great advantage of the combination two-stage superheater comes from the combination of the tendency towards a rising superheat with the convection superheater with the opposite tendency of the radiant-heat type, which has a falling temperature curve with load, the resultant being a flatter curve than is possible with either type alone.

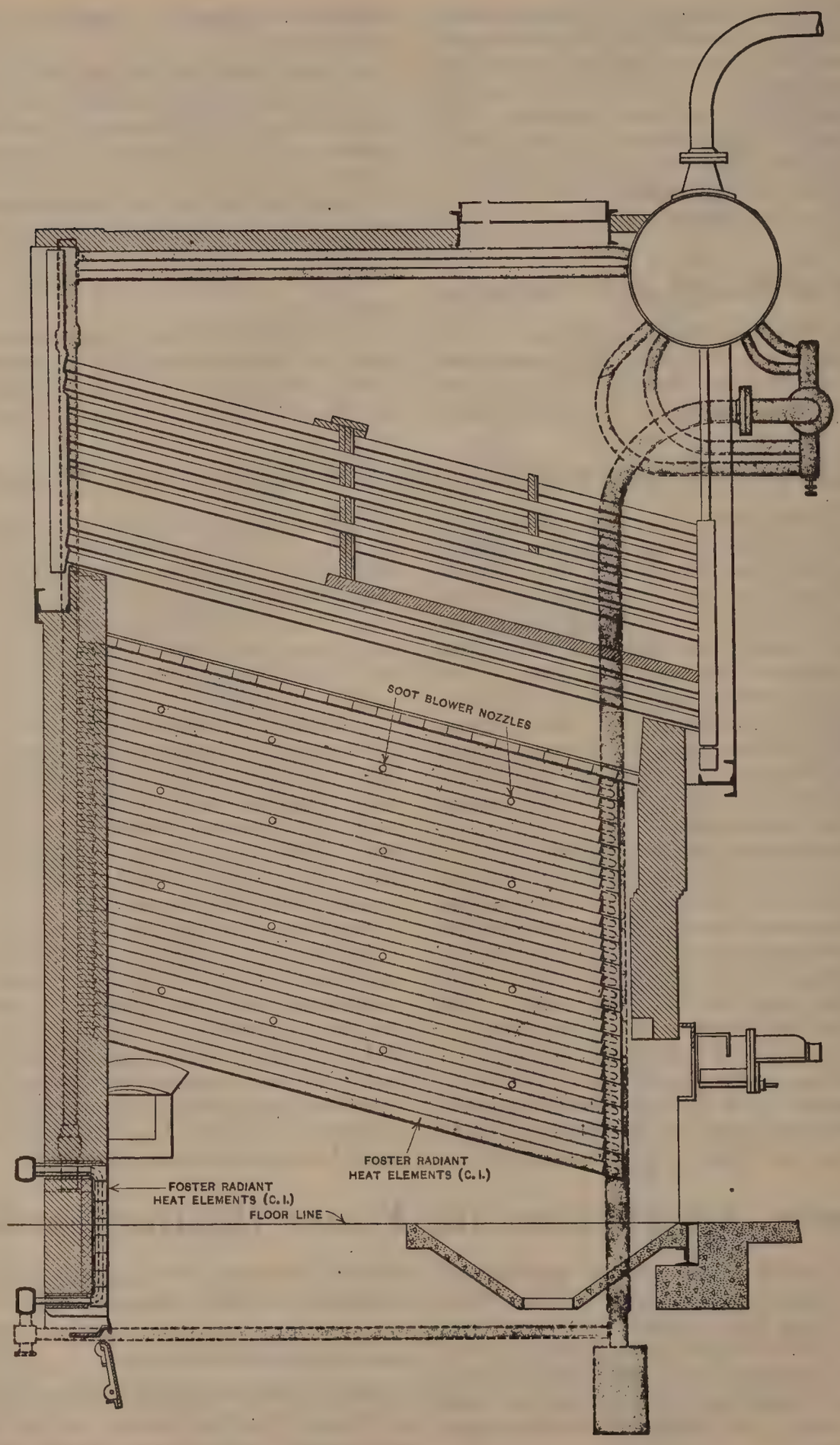
Another point already mentioned is that a change in furnace efficiency will not have the same effect with a two-stage superheater as with a single-stage, because falling CO_2 causes a rise of temperature with a convection type superheater and a falling temperature with a radiant-heat type. In this case again the tendencies of the two superheaters oppose one another, so that change in furnace conditions has very little effect upon the final steam temperature obtained.

Special Applications for Foster Heating Surface

IN addition to the production of superheated steam for economy in power plants, many other special uses have been found for the Foster superheater. The fact that it superheats steam to any desired temperature means that low-pressure or exhaust steam may be utilized for high temperature uses, in place of high-pressure saturated steam.

Foster Superheaters, Preheaters, Cracking Stills, etc., have found wide application in many industrial processes involving the heating or heat treatment of oils, chemical gases, liquids, air, etc., and in these fields also our engineers have had considerable experience.

If you have in mind some special application of Foster Heating Surface, we will welcome the opportunity to make suggestions, and will regard as confidential such information as should be placed in our hands.



Foster Water-cooled Furnace Walls and Foster Water Back in a 928-hp. Babcock & Wilcox Cross-drum Boiler. One of four similar installations in the plant of Consumers Power Company, Zilwaukee, Mich. These boilers are also equipped with Foster Radiant-Heat Type Superheaters, located in the rear furnace wall

Foster Water-cooled Furnace Walls

WITHIN the past few years improvements in design and operation of furnaces and fuel-burning equipment have made it practicable to reduce the amount of air supplied for combustion. This condition applies generally to all classes of fuel-burning apparatus—coal, oil and gas. The effect of this has been to increase CO_2 in flue gases and to raise furnace temperatures, all of which has resulted in considerably higher fuel efficiencies under normal operating conditions than were previously shown. Higher furnace temperatures, however, have been accompanied by increased difficulties in maintenance of furnace brickwork. For a number of years—particularly with certain fuels—this has been a troublesome operating problem, the satisfactory solution of which has now been rendered more difficult, first, by higher furnace temperatures, as noted above, and second, by increases in the size of furnaces and ratings at which boilers are operated. Such increases are also developments of recent years.

All of this has created a widespread demand for some means of protecting furnace brickwork or replacing it with other construction that will stand up more satisfactorily under modern operating conditions. To meet this demand we have developed the design, and have made a number of installations of Foster Water-Cooled Furnace Walls. These walls consist of cold-drawn seamless steel tubes on which are shrunk heavy rectangular cast iron-blocks about 6 inches long and 4 inches wide. These elements are installed on close centers so that the open space between adjacent elements is approximately ⅛ inch. The faces toward the fire form a continuous flat wall which has been described as being built of "*cast-iron bricks water cooled.*"

Elements are connected at suitable intervals to stiffening and supporting steel work at the rear. The space immediately behind the elements is filled with insulating material and the space in back of that closed in with heavy steel plates or in some cases with brick curtain walls. Foster Water-cooled Furnace Walls are designed not to extend above the lower row of boiler tubes and where desired the construction includes supports which provide a solid foundation for the brick wall or walls above.

Elements are expanded at each end into headers which are supported on structural members and are connected to the boiler at points above and below the water line so that circulation is maintained through water-cooled walls the same as through various parts of the boiler.

Where heating surface is exposed to direct action of impinging flames in which combustion is taking place, or is in intimate contact with a high-temperature fuel bed, as in the case of water-cooled walls in the clinker pit, it is known that unless the water circulation is continuous and rapid there will be overheating with blistering and burning. It is next to impossible, however, to connect surfaces of this sort so that a continuous and rapid circulation is maintained at all times. Due to the necessity of keeping down to a minimum the number of connections to the boiler drums, there are bound to be points in the circulating system where any quick absorption of heat would impede, stop or even reverse the circulation and when this occurs there is rapid local overheating on the exposed side of a thin tube which causes trouble. With the large amount of metal in the blocks fitted to our tubes a time element is introduced and a rapid absorption of heat in one place is distributed over a much greater area of surface in the water-containing tubes, so that the tendency for local generation of steam impeding or reversing the circulation is reduced. At the same time the effect of the rapid absorption of heat in face of the element in raising the surface temperature is also reduced and therefore there is not the necessity for extreme care in the proportioning and arrangement of the water circulating system.

In other words, we have provided a system which can be practically introduced in the most exposed positions of a boiler furnace without danger, and without the necessity for providing elaborate water circulation arrangements.

We have also provided a flat external surface which has a minimum tendency to catch clinker and dust but which can be most readily cleaned when, as is always the case, there is some accumulation. Where used to line the rear wall of the clinker pit, Foster Water-cooled Furnace Walls reduce trouble due to clinkering and make it practicable to carry higher ratings and to burn cheaper grades of coal than would be possible without them. Where used to replace, not merely to protect, brickwork in other parts of the furnace, Foster Water-cooled Furnace Walls eliminate the initial and maintenance costs of the walls replaced and substitute a durable rugged construction on which maintenance costs are practically nothing, and one which can be relied upon to meet satisfactorily any demand for peak-load operation, continuous over long periods or intermittent as required.

Properties of Steam

t.—Temperatures in degrees fahr. v.—Specific volume in cu. ft. per lb. h.—Total heat in B. t. u. per lb.

Pressure in pounds per sq. in. Absol.	Gauge		Water	Saturated steam	Degrees of superheat 50°	100°	150°	200°	250°	300°
15	0.3	t.	213.0	213.0	263.0	313.0	363.0	413.0	463.0	513.0
		v.	0.02	26.27	28.40	30.46	32.50	34.53	36.56	38.58
		h.	181.0	1,150.7	1,174.2	1,197.6	1,221.0	1,244.4	1,267.7	1,291.1
16	1.3	t.	216.3	216.3	266.3	316.3	366.3	416.3	466.3	516.3
		v.	0.02	24.74	26.73	28.67	30.59	32.50	34.40	36.29
		h.	184.4	1,152.0	1,175.5	1,198.0	1,222.4	1,245.8	1,269.2	1,292.6
17	2.3	t.	219.4	219.4	269.4	319.4	369.4	419.4	469.4	519.4
		v.	0.02	23.38	25.26	27.09	28.90	30.69	32.48	34.26
		h.	187.5	1,153.1	1,176.7	1,200.2	1,223.6	1,247.1	1,270.5	1,294.0
18	3.3	t.	222.4	222.4	272.4	322.4	372.4	422.4	472.4	522.4
		v.	0.02	22.16	23.94	25.67	27.39	29.08	30.77	32.46
		h.	190.5	1,154.2	1,177.8	1,201.3	1,224.8	1,248.3	1,271.8	1,295.3
19	4.3	t.	225.2	225.2	275.2	325.2	375.2	425.2	475.2	525.2
		v.	0.02	21.07	22.76	24.40	26.03	27.64	29.24	30.8
		h.	193.4	1,155.2	1,178.9	1,202.4	1,226.0	1,249.5	1,273.0	1,296.5
20	5.3	t.	228.0	228.0	278.0	328.0	378.0	428.0	478.0	528.0
		v.	0.02	20.08	21.69	23.25	24.80	26.33	27.85	29.37
		h.	196.1	1,156.2	1,179.9	1,203.5	1,227.1	1,250.6	1,274.1	1,297.6
30	15.3	t.	250.4	250.4	300.4	350.4	400.4	450.4	500.4	550.4
		v.	0.02	13.74	14.83	15.89	16.93	17.97	18.99	20.00
		h	218.8	1,163.9	1,188.1	1,212.1	1,236.0	1,259.7	1,283.4	1,307.1
40	25.3	t.	267.3	267.3	317.3	367.3	417.3	467.3	517.3	567.3
		v.	0.02	10.49	11.33	12.13	12.93	13.70	14.48	15.2
		h.	236.0	1,169.4	1,194.0	1,218.4	1,242.4	1,266.4	1,290.3	1,314.1
50	35.3	t.	281.0	281.0	331.0	381.0	431.0	481.0	531.0	581.0
		v.	0.02	8.51	9.19	9.84	10.48	11.11	11.74	12.3
		h.	250.1	1,173.6	1,198.8	1,223.4	1,247.7	1,271.8	1,295.8	1,319.7
60	45.3	t.	292.7	292.7	342.7	392.7	442.7	492.7	542.7	592.7
		v.	0.02	7.17	7.75	8.30	8.84	9.36	9.89	10.4
		h.	262.1	1,177.0	1,202.6	1,227.6	1,252.1	1,276.4	1,300.4	1,324.3
70	55.3	t.	302.9	302.9	352.9	402.9	452.9	502.9	552.9	602.9
		v.	0.02	6.20	6.71	7.18	7.65	8.11	8.56	9.0
		h.	272.6	1,179.8	1,205.9	1,231.2	1,255.8	1,280.2	1,304.3	1,328.3
80	65.3	t.	312.0	312.0	362.0	412.0	462.0	512.0	562.0	612.0
		v.	0.02	5.47	5.92	6.34	6.75	7.17	7.56	7.9
		h.	282.0	1,182.3	1,208.8	1,234.3	1,259.0	1,283.6	1,307.8	1,331.9
90	75.3	t.	320.3	320.3	370.3	420.3	470.3	520.3	570.3	620.3
		v.	0.02	4.89	5.29	5.67	6.04	6.40	6.76	7.1
		h.	290.5	1,184.4	1,211.4	1,237.2	1,262.0	1,286.6	1,310.8	1,334.9
100	85.3	t.	327.8	327.8	377.8	427.8	477.8	527.8	577.8	627.8
		v.	0.02	4.43	4.79	5.14	5.47	5.80	6.12	6.4
		h.	298.3	1,186.3	1,213.8	1,239.7	1,264.7	1,289.4	1,313.6	1,337.8
110	95.3	t.	334.8	334.8	384.8	434.8	484.8	534.8	584.8	634.8
		v.	0.02	4.05	4.38	4.70	5.01	5.31	5.61	5.9
		h.	305.5	1,188.0	1,215.9	1,242.0	1,267.1	1,291.9	1,316.2	1,340.4
120	105.3	t.	341.3	341.3	391.3	441.3	491.3	541.3	591.3	641.3
		v.	0.02	3.73	4.04	4.33	4.62	4.89	5.17	5.4
		h.	312.3	1,189.6	1,217.9	1,244.1	1,269.3	1,294.1	1,318.4	1,342.7
130	115.3	t.	347.4	347.4	397.4	447.4	497.4	547.4	597.4	647.4
		v.	0.02	3.45	3.74	4.02	4.28	4.54	4.80	5.0
		h.	318.6	1,191.0	1,219.7	1,246.1	1,271.4	1,296.2	1,320.6	1,344.9
140	125.3	t.	353.1	353.1	403.1	453.1	503.1	553.1	603.1	653.1
		v.	0.02	3.22	3.49	3.75	4.00	4.24	4.48	4.7
		h.	324.6	1,192.2	1,221.4	1,248.0	1,273.3	1,298.2	1,322.6	1,346.9
150	135.3	t.	358.5	358.5	408.5	458.5	508.5	558.5	608.5	658.5
		v.	0.02	3.01	3.27	3.51	3.75	3.97	4.19	4.4
		h.	330.2	1,193.4	1,223.0	1,249.6	1,275.1	1,300.0	1,324.5	1,348.8
160	145.3	t.	363.6	363.6	413.6	463.6	513.6	563.6	613.6	663.6
		v.	0.02	2.83	3.07	3.30	3.53	3.74	3.95	4.1
		h.	335.6	1,194.5	1,224.5	1,251.3	1,276.8	1,301.7	1,326.2	1,350.6

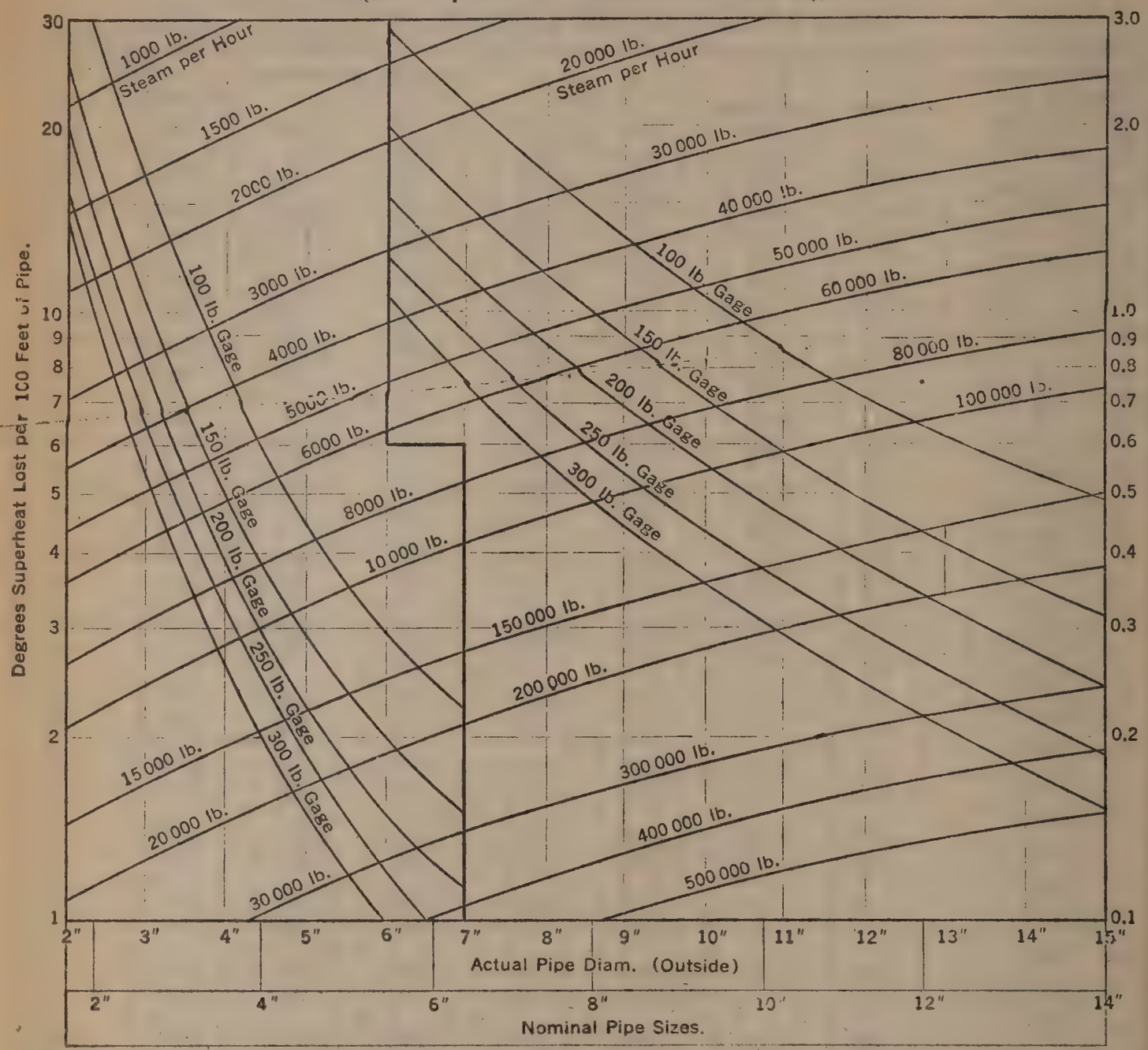
Properties of Steam — *Continued*

(*Marks & Davis, by permission of Longmans, Green & Co.*)

Pressure in pounds per sq. in. Absol.	Gauge		Water	Saturated steam	Degrees of superheat 50°	100°	150°	200°	250°	300°
170	155.3	t.	368.5	368.5	418.5	468.5	518.5	568.5	618.5	668.5
		v.	0.02	2.68	2.91	3.12	3.34	3.54	3.73	3.92
		h.	340.7	1,195.4	1,225.9	1,252.8	1,278.4	1,303.3	1,327.9	1,352.3
180	165.3	t.	373.1	373.1	423.1	473.1	523.1	573.1	623.1	673.1
		v.	0.02	2.53	2.75	2.96	3.16	3.35	3.54	3.72
		h.	345.6	1,196.4	1,227.2	1,254.3	1,279.9	1,304.8	1,329.5	1,353.9
190	175.3	t.	377.6	377.6	427.6	477.6	527.6	577.6	627.6	677.6
		v.	0.02	2.41	2.62	2.81	3.00	3.19	3.37	3.55
		h.	350.4	1,197.3	1,228.6	1,255.7	1,281.3	1,306.3	1,330.9	1,355.5
200	185.3	t.	381.9	381.9	431.9	481.9	531.9	581.9	631.9	681.9
		v.	0.02	2.29	2.49	2.68	2.86	3.04	3.21	3.38
		h.	354.9	1,198.1	1,229.8	1,257.1	1,282.6	1,307.7	1,332.4	1,357.0
210	195.3	t.	386.0	386.0	436.0	486.0	536.0	586.0	636.0	686.0
		v.	0.02	2.19	2.38	2.56	2.74	2.91	3.07	3.23
		h.	359.2	1,198.8	1,231.0	1,258.4	1,284.0	1,309.0	1,333.7	1,358.1
220	205.3	t.	389.9	389.9	439.9	489.9	539.9	589.9	639.9	689.9
		v.	0.02	2.09	2.28	2.45	2.62	2.78	2.94	3.10
		h.	363.4	1,199.6	1,232.2	1,259.6	1,285.2	1,310.3	1,335.1	1,359.8
230	215.3	t.	393.8	393.8	443.8	493.8	543.8	593.8	643.8	693.8
		v.	0.02	2.00	2.18	2.35	2.51	2.67	2.82	2.97
		h.	367.5	1,200.2	1,233.2	1,260.7	1,286.5	1,311.6	1,336.3	1,361.0
240	225.3	t.	397.4	397.4	447.4	497.4	547.4	597.4	647.4	697.4
		v.	0.02	1.92	2.09	2.26	2.42	2.57	2.71	2.85
		h.	371.4	1,200.9	1,234.3	1,261.9	1,287.6	1,312.8	1,337.6	1,362.3
250	235.3	t.	401.0	401.0	451.0	501.0	551.0	601.0	651.0	701.0
		v.	0.02	1.85	2.02	2.17	2.33	2.47	2.61	2.75
		h.	375.2	1,201.5	1,235.4	1,263.0	1,288.8	1,313.9	1,338.8	1,363.5
260	245.3	t.	404.5	404.5	454.5	504.5	554.5	604.5	654.5	704.5
		v.	0.02	1.78	1.94	2.10	2.24	2.39	2.52	2.65
		h.	378.9	1,202.1	1,236.4	1,267.1	1,289.9	1,315.1	1,340.0	1,364.7
270	255.3	t.	407.9	407.9	457.9	507.9	557.9	607.9	657.9	707.9
		v.	0.02	1.72	1.87	2.02	2.16	2.30	2.43	2.56
		h.	382.5	1,202.6	1,237.4	1,265.2	1,290.9	1,316.2	1,341.1	1,365.9
280	265.3	t.	411.2	411.2	461.2	511.2	561.2	611.2	661.2	711.2
		v.	0.02	1.66	1.81	1.95	2.09	2.22	2.35	2.48
		h.	386.0	1,203.1	1,238.4	1,266.2	1,291.9	1,317.2	1,342.2	1,367.0
290	275.3	t.	414.4	414.4	464.4	514.4	564.4	614.4	664.4	714.4
		v.	0.02	1.60	1.75	1.89	2.02	2.15	2.28	2.40
		h.	389.4	1,203.6	1,239.3	1,267.1	1,293.0	1,318.3	1,342.2	1,368.0
300	285.3	t.	417.5	417.5	467.5	517.5	567.5	617.5	667.5	717.5
		v.	0.02	1.55	1.69	1.83	1.96	2.09	2.21	2.33
		h.	392.7	1,204.1	1,240.3	1,268.2	1,294.0	1,319.3	1,344.3	1,369.2
310	295.3	t.	420.5	420.5	470.5	520.5	570.5	620.5	670.5	720.5
		v.	0.02	1.502	1.64	1.78	1.90	2.02	2.14	2.25
		h.	395.9	1,204.5	1,241.1	1,269.1	1,294.9	1,320.3	1,345.3	1,370.2
320	305.3	t.	423.4	423.4	473.4	523.4	573.4	623.4	673.4	723.4
		v.	0.02	1.456	1.59	1.72	1.85	1.96	2.08	2.19
		h.	399.1	1,204.9	1,242.0	1,270.0	1,295.9	1,321.3	1,346.3	1,371.3
330	315.3	t.	426.3	426.3	476.3	526.3	576.3	626.3	676.3	726.3
		v.	0.02	1.413	1.54	1.67	1.80	1.91	2.02	2.13
		h.	402.2	1,205.3	1,242.9	1,270.9	1,296.8	1,322.2	1,347.3	1,372.3
340	325.3	t.	429.1	429.1	479.1	529.1	579.1	629.1	679.1	729.1
		v.	0.02	1.372	1.50	1.63	1.75	1.86	1.97	2.08
		h.	405.3	1,205.7	1,243.8	1,271.8	1,297.8	1,323.2	1,348.3	1,373.3
350	335.3	t.	431.9	431.9	481.9	531.9	581.9	631.9	681.9	731.9
		v.	0.02	1.334	1.46	1.58	1.70	1.81	1.92	2.02
		h.	408.3	1,206.1	1,244.6	1,272.7	1,298.7	1,324.1	1,349.1	1,374.3

Loss of Superheat per 100 Lineal Feet of Pipe

at an average temperature difference of 450 deg. fahr.



*Standard rates of transfer in B.t.u. per hour per square foot of external pipe surface per degree mean temperature difference

Nominal pipe size—	2 in.	4 in.	6 in.	8 in.	10 in.	12 in.	14 in.
Transfer—	.41	.29	.26	.24	.23	.22	.21

Above based on 85 per cent Magnesia—2½-in. thick on 2-in. pipe: 3-in. thick on 4-in. to 14-in. pipe.

(*H. W. Johns-Manville Co.)

The above curves are figured on the basis of pressure loss of 1 per cent of gauge pressure at all points on the pressure curve.

The superheat losses shown are based upon the standard rates of heat transfer as determined by laboratory tests and standard thickness of covering as mentioned in the table.

Under ordinary power plant conditions, actual losses will be in excess of those shown, by from 25 to 100 per cent, depending upon the condition of the covering, care with which same is applied, etc.

Converting Thermometer Scales

To convert Centigrade into Fahrenheit degrees quickly, in one's mind, a short method is to "Double, subtract one-tenth, add 32." *Example:*

100° C. × 2 = 200; — 20 = 180; + 32 = 212° F.
0° C. × 2 = 0; — 0 = 0; + 32 = 32° F.
10° C. × 2 = 80; — (8) = 72; + 32 = 40° F.

Carrying Capacity of Extra Heavy Steam Pipes

Pipe size, inches	Inside area, inches	Gauge pressure in pounds per square inch								
		600	500	400	300	250	200	150	100	50
		Pounds of steam per hour								
1	.71	2,400	1,975	1,585	1,200	1,015	830	646	458	267
1¼	1.27	4,290	3,530	2,835	2,145	1,815	1,485	1,155	820	477
1½	1.75	5,920	4,870	3,910	2,960	2,500	2,050	1,590	1,130	658
2	2.93	9,900	8,150	6,540	4,950	4,180	3,430	2,670	1,890	1,102
2½	4.20	11,200	11,700	9,370	7,100	6,000	4,910	3,820	2,710	1,580
3	6.56	22,200	18,250	14,620	11,100	9,380	7,670	5,970	4,230	2,240
3½	8.85	29,900	24,600	19,720	14,950	12,540	10,360	8,050	5,710	3,330
4	11.41	38,700	31,800	25,500	19,350	16,350	13,100	10,410	7,388	4,300
4½	14.18	48,000	39,400	31,600	23,950	20,250	16,600	12,900	9,150	5,330
5	18.19	61,500	50,500	40,500	30,700	26,000	22,300	16,540	11,720	6,840
6	25.93	87,500	72,100	57,800	43,800	37,000	31,500	23,600	16,750	9,750
7	34.47	116,600	96,000	77,000	58,300	49,250	40,300	31,400	22,210	12,970
8	44.18	149,500	123,000	98,600	74,700	63,100	51,700	40,200	28,500	16,600
9	58.42	197,500	162,300	130,300	98,700	83,500	68,300	53,100	37,700	21,950
10	74.66	252,400	207,800	166,500	126,200	105,800	87,400	68,000	48,200	28,100
11	90.76	307,000	252,100	202,200	153,400	128,600	106,200	82,600	58,500	34,100
12	108.43	366,000	274,000	242,000	183,400	155,000	127,000	98,600	70,000	40,800
13	132.73	448,500	335,500	296,000	224,000	189,600	155,300	120,800	85,600	49,900
14	153.94	520,000	388,500	343,000	260,000	220,000	180,000	140,000	99,250	57,800
16	176.71	597,000	447,000	394,000	298,500	252,400	207,000	160,900	114,000	66,500
18	226.98	770,000	574,000	501,000	384,000	323,000	265,500	206,500	146,500	85,400
Superheat		Steam velocity in feet per minute								
0		6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
50° fahr		6,800	6,660	6,630	6,550	6,530	6,520	6,520	6,500	6,500
100° "		7,500	7,330	7,280	7,100	7,060	7,030	7,000	6,970	6,950
150° "		8,200	7,930	7,820	7,580	7,550	7,500	7,480	7,160	7,100
200° "		8,800	8,500	8,350	8,070	8,050	7,950	7,910	7,830	7,830
250° "		9,300	9,050	8,850	8,550	8,500	8,400	8,370	8,320	8,270

Relative Fuel Value of Coal and Oil

Gross boiler efficiency with oil fuel	*Net evaporation from and at 212 deg. fahr. per pound of oil	Water evaporated from and at 212 deg. fahr. per pound of coal							
		5	6	7	8	9	10	11	12
		Pounds of oil equal to one pound of coal							
73	13.90	.36	.43	.50	.58	.65	.72	.79	.86
74	14.10	.35	.43	.50	.57	.64	.71	.78	.85
75	14.29	.35	.42	.49	.56	.63	.70	.77	.84
76	14.49	.35	.41	.48	.55	.62	.69	.76	.83
77	14.69	.34	.41	.48	.54	.61	.68	.75	.82
78	14.88	.34	.40	.47	.54	.61	.67	.74	.81
79	15.08	.33	.40	.46	.53	.60	.66	.73	.80
80	15.27	.33	.39	.46	.52	.59	.66	.72	.79
81	15.47	.32	.39	.45	.52	.58	.65	.71	.78
82	15.66	.32	.38	.45	.51	.57	.64	.70	.77
83	15.86	.32	.38	.44	.50	.57	.63	.69	.76

*Net evaporation equals gross evaporation less 2% for atomizing oil. Heat value of oil equals 19,000 B.t.u. One ton of coal weighs 2,240 pounds. One barrel of oil weighs 336 pounds. One gallon of oil weighs 8 pounds.

Foster Engineering and Erecting Service

THE desirability of using superheat in any power plant is dependent upon individual plant conditions, and unless the superheater installation exactly meets the specific conditions, full benefits cannot be obtained.

Those considering the use of superheat as a means of combating high fuel and labor costs, obtaining extra capacity from existing equipment, etc., can therefore best serve their own interests by consulting our engineers from the start.

Applications to all makes of boilers and all industries, have given us a wealth of performance data upon which to base our recommendations and assure correct superheater design.

If your plant presents a problem for which superheat might offer the solution, tell us the number, type and size of your boilers, types and sizes of engines, turbines and steam-driven pumps, the kind and amount of fuel you burn, whether fired by hand or mechanical stoker, type of valves and piping used, and if possible send us a blue print of layout. We will gladly and without charge advise you what degree of superheat should be used, the proper arrangement of superheater, and the practical improvements that should result.

Where desired, our Service Department assumes complete supervision of any Foster Superheater installation ready for operation.

A. EUGENE MICHEL
TECHNICAL ADVERTISING

DEFENDANT'S EXHIBIT C.

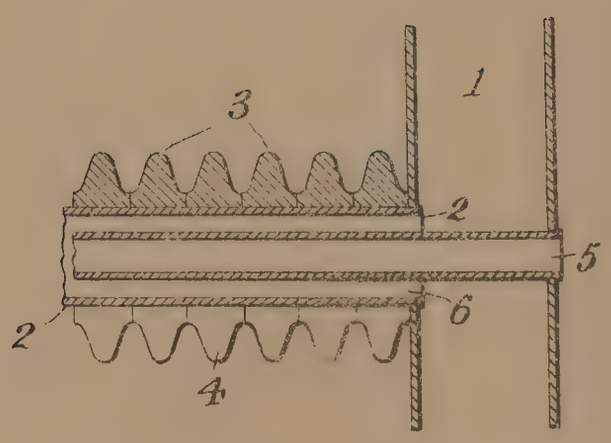
No. 744,323. PATENTED NOV. 17, 1903.

E. H. FOSTER.

TUBE FOR SUPERHEATERS.

APPLICATION FILED JUNE 25, 1903.

NO MODEL.



Witnesses:
Raphael Netter
S. S. Dunham

Ernest H. Foster, Inventor
by Kerr, Page & Cooper, Attys

. 744,323. Patented November 17, 1903.

UNITED STATES PATENT OFFICE.

ERNEST H. FOSTER, OF NEW YORK, N. Y.

TUBE FOR SUPERHEATERS.

SPECIFICATION forming part of Letters Patent No. 744,323, dated November 17, 1903.

Application filed June 25, 1903. Serial No. 162,983. (No model.)

ll whom it may concern:

e it known that I, ERNEST H. FOSTER, a en of the United States, residing at New k, county and State of New York, have in- ted certain new and useful Improvements 'ubes for Superheaters, of which the fol- ing is a specification, reference being had he drawing accompanying and forming t of the same.

he invention which forms the subject of present application relates to apparatus heating or superheating steam or other es or vapors, and pertains more particu- y to the construction of the tubes through ch the gases or vapors pass to be exposed he heat. In this connection it is recog- ed that a superheater-tube should have ngth, uniformity of metal, and smooth rior, the latter characteristic being de- ble in order to reduce to a minimum the tion of the steam in passing therethrough. s also desirable to expose as large a sur- e of metal to the heat as possible, for ob- us reasons. To secure this advantage, it been proposed to make the exterior of tube corrugated. In this case the method ally employed for making such a pipe is casting; but this is costly, and it is not cticable to make the pipe in the long gths desired. To obviate this difficulty, ave devised my present invention, which sesses the combined advantages enumer- d above.

o these ends it consists, broadly stated, a tube having the desired strength sur- nded by closely-fitting rings of cast or er metal.

t further consists in the novel features and nbinations hereinafter described, and more ticularly set forth in the claim.

Referring now to the drawing, which shows embodiment of the invention in section, one of the headers to which the tubes are ally connected. The tube proper is indi- ed by 2 and is preferably made of iron or el wrought or drawn into a pipe. It may of any strength desired and secured to the aders in any convenient way. As shown, its interior is smooth, and therefore causes a minimum amount of friction with the passing vapor.

Surrounding the pipe and fitting the same snugly is a series of rings 3. These rings are preferably made of cast metal and may be split, as shown at 4. In order to secure a maximum amount of metal around the tube and to thoroughly protect the same, they should preferably be placed in contact with each other instead of spaced apart, and in such case they should be tapered in cross-section, as shown, to form the corrugations. It is obvious, of course, that the rings may be made in groups of several or any number, if desired, and they may be assembled on the foundation-tube before or after it is secured to one of the headers, whichever is most convenient under the circumstances. They may of course be easily removed when desired.

The rings may be described as "continuous," in the sense that each consists of a single part instead of a plurality of parts or sections. Splitting, when that construction is desired, does not affect the continuity of the ring in the sense in which the term is here used, as will be readily understood.

In the particular type of superheater illustrated a pipe or core 5 extends through the tube 2 from header to header and is open at the ends for the passage of the heated gases and products of combustion to which the apparatus is exposed. The steam is thus confined to the annular space 6 and is exposed to the heat on both sides.

It will now be seen that a tube constructed in accordance with my invention will possess the combined advantages enumerated above. The necessary strength is obtained by the foundation-tube 2, while the desired resistance to the deteriorating effect of heat and corrosion by the heated gases, rigidity of form, large heat-absorbing surface, and maximum amount of metal for storage of heat are secured by the inexpensive rings in contact with and surrounding the external surface of the body.

The invention is of course capable of va

rious embodiments, and I therefore do not consider myself limited to the form herein specifically shown and described; but

What I claim is—

A tube for steam-superheaters, comprising a foundation-tube and a series of independent, continuous, cast-metal tapered rings, in contact with each other, and fitting snugly on the foundation-tube, substantially as described and for the purposes set forth.

ERNEST H. FOSTER.

Witnesses:

M. LAWSON DYER,

S. S. DUNHAM.

DEFENDANT'S EXHIBIT D.

No. 886,516. PATENTED MAY 5, 1908.

R. KABLITZ.

FEED WATER HEATER FOR BOILERS.

APPLICATION FILED MAR. 6, 1907. 2 SHEETS—SHEET 1.

Fig. I

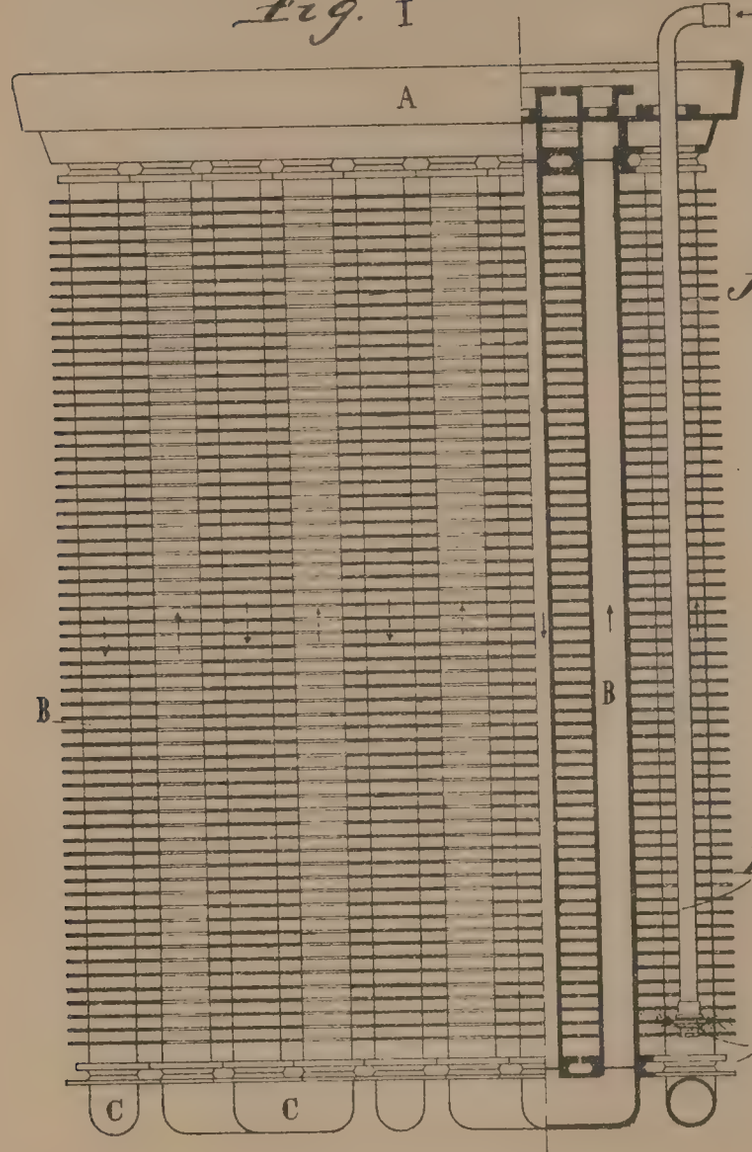


Fig. II

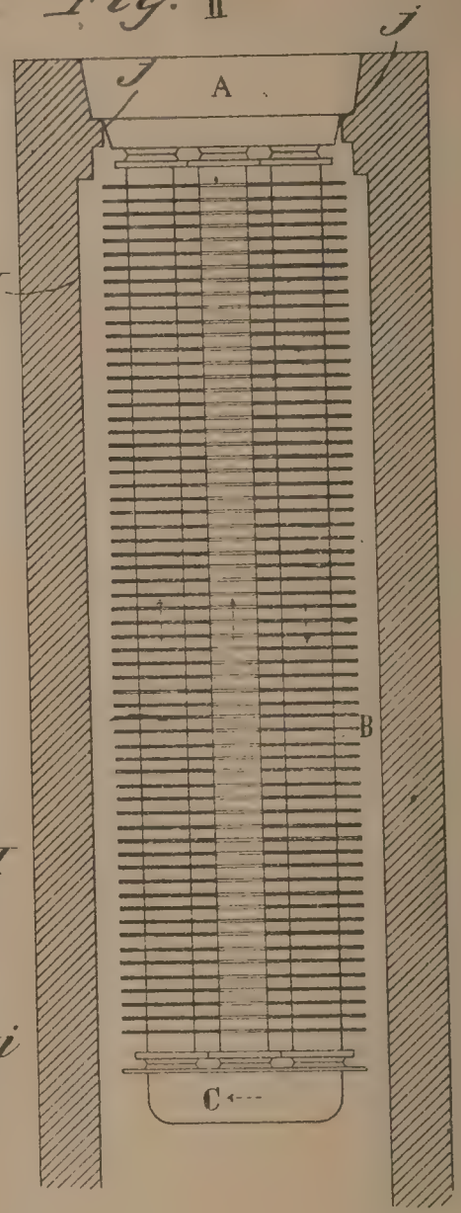
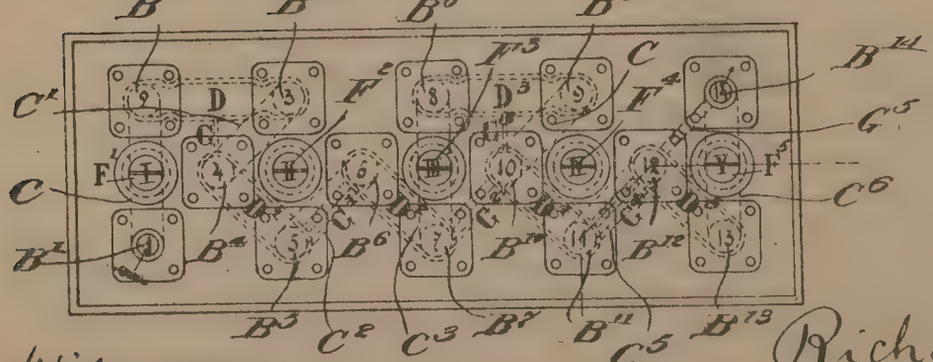


Fig. III



Witnesses:
C. Heymann
L. Waldman

Inventor
Richard Kablitz
by P. Singer atty.

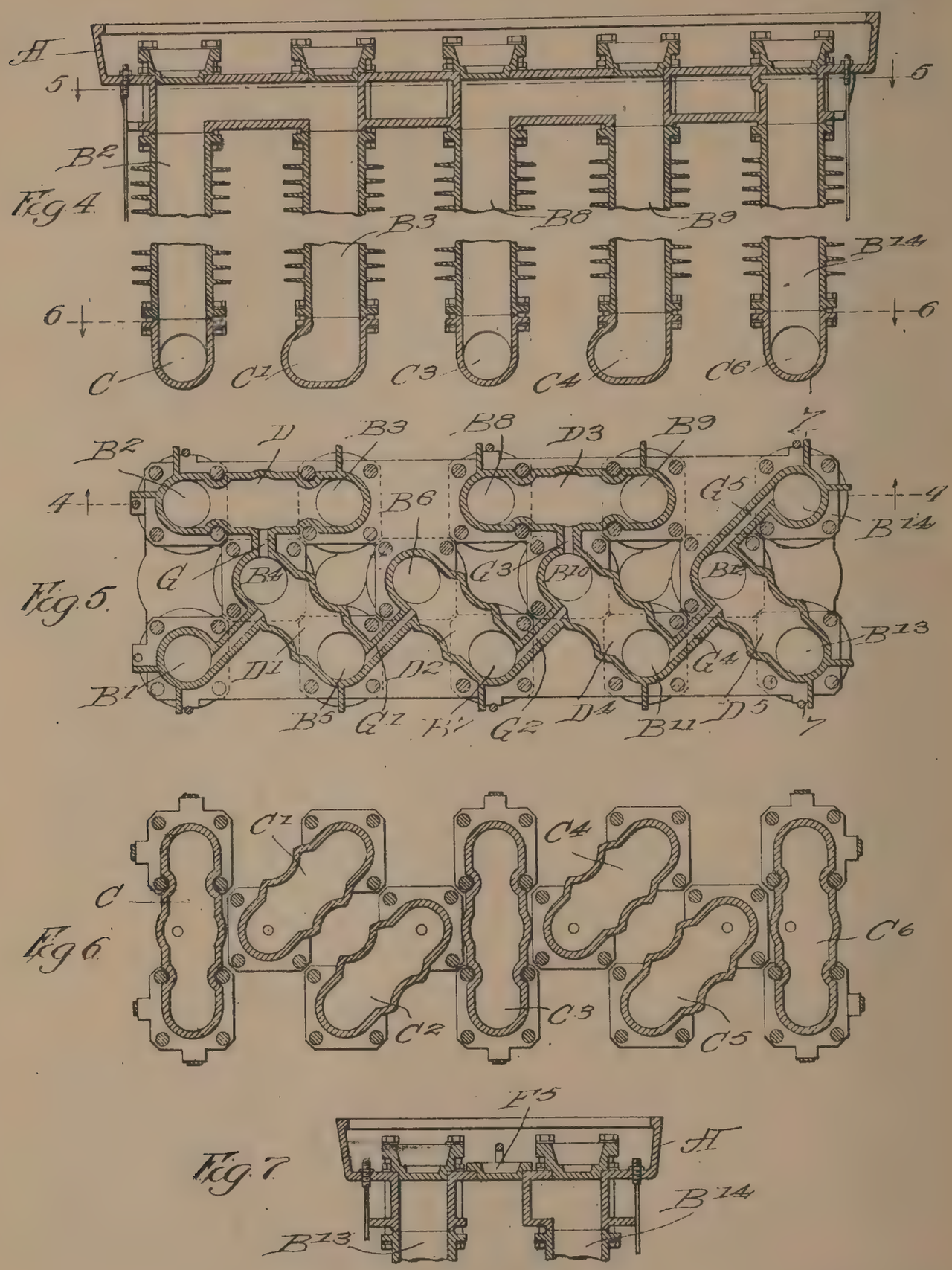
No. 886,516. PATENTED MAY 5, 1908.

R. KABLITZ.

FEED WATER HEATER FOR BOILERS.

APPLICATION FILED MAR. 6, 1907.

2 SHEETS—SHEET 2.



Witnesses
C. H. Crawford
E. Schallinger

Inventor
Richard Kablitz
By R. Singer
Atty

UNITED STATES PATENT OFFICE.

RICHARD KABLITZ, OF RIGA, RUSSIA.

FEED-WATER HEATER FOR BOILERS.

No. 886,516. Specification of Letters Patent. Patented May 5, 1908.

Application filed March 6, 1907. Serial No. 360,866.

To all whom it may concern:

Be it known that I, RICHARD KABLITZ, of Riga, Russia, have invented certain new and useful Improvements in Feed-Water Heaters, of which the following is a full specification.

This invention relates to improvements in feed water heaters for boilers and is designed to receive the feed water, prior to its admission to the boiler and heat the same.

The novel feature of the invention consists in the provision of a bearing or supporting member provided in its interior with a plurality of pipe connecting channels and gas by-passes connecting the same together with a plurality of ribbed tubes or pipes registering with said channels and connected with each other in such a manner that the feed water flows serially through all of said pipes from the point of ingress to the point of egress, the said supporting body being provided with cleaning openings and the said tubes or pipes being grouped about said openings in such a manner that the exterior ribbed portions of a plurality of pipes will be accessible to a cleaning device inserted through any one of said openings.

The invention will be more fully described in connection with the accompanying drawing and will be particularly pointed out and ascertained in and by the appended claims.

In the drawing: Figure 1, is a view in side elevation, partly broken away, of a heater embodying the main features of my invention. Fig. 2, is an end elevation of the heater showing the same disposed in a chamber adapted to receive the products of combustion from a furnace. Fig. 3, is a plan view of the heater. Fig. 4, is a sectional view on line 4—4 of Fig. 5. Fig. 5 is a sectional view on line 5—5 of Fig. 4. Fig. 6, is a sectional view on line 6—6 of Fig. 4. Fig. 7, is a sectional view on line 7—7 of Fig. 5.

Like characters of reference designate similar parts throughout the different figures of the drawing.

The supporting or bearing body is designated at A and is of hollow construction. Said body A is provided with a plurality of cleaning openings designated by F' to F^5 inclusive, there being five of such openings shown and disposed in alinement with the longitudinal axis of said body A. Said openings are for the purpose of admitting a cleaning device, the purpose of which will hereinafter more fully appear. A plurality of pipe connecting channels are arranged in said body A and are designated by D to D^5 inclusive. Said channels are shown in dotted lines in Fig. 3 and adjacent channels are shown connected by by-passes indicated by G to G^5 inclusive. A plurality of ribbed tubes or pipes is secured to the member A and said pipes are designated by B' to B^{14} inclusive, there being 14 of said pipes and the point of ingress being at pipe B' while the point of egress is at pipe B^{14}. Said pipes are connected with each other at their ends remote from the body A by connections C' to C^6 inclusive and the specific arrangement of said connections and also the arrangement of the pipes with respect to the channels is as follows:—

Pipe B' is connected with pipe B^2 by connection C, pipe B^2 is connected with pipe B^3 by channel D, pipe B^3 is connected with pipe B^4 by connection C', pipe B^4 is connected with pipe B^5 by channel D', pipe B^5 is connected with pipe B^6 by connection C^2, pipe B^6 is connected with pipe B^7 by channel D^2, pipe B^7 is connected with pipe B^8 by connection C^3, pipe B^8 is connected with pipe B^9 by channel D^3, pipe B^9 is connected with pipe B^{10} by connection C^4, pipe B^{10} is connected with pipe B^{11} by channel D^4, pipe B^{11} is connected with pipe B^{12} by connection C^5, pipe B^{12} is connected with pipe B^{13} by channel D^5 and pipe B^{13} is connected with pipe B^{14}, which is the point of egress, by connection C^6. The arrangement of the by-passes is as follows:—Channels D and D' are connected by by-pass G, channels D' and D^2 are connected by by-pass G', channels D^2 and D^4 are connected by by-pass G^2, channels D^3 and D^4 are connected by by-pass G^3, channels D^4 and D^5 are connected by by-pass G^4 and channel D^5 is connected with pipe B^{14} by by-pass G^5.

It will be noted that the pipes B' to B^{14} inclusive are grouped about the several openings F' to F^5 inclusive so that when a cleaning device is inserted through any one of said openings it will be in close proximity with the exterior portions of a plurality of pipes thereby greatly facilitating the cleaning operation. The ribs on said pipes present surfaces, which collectively speaking are of a relatively great area, and said surfaces rapidly collect portions of soot from the products of combustion and as they lose their efficiency when coated with soot it is essential to clean the same. The improved

arrangement hereinbefore set forth affords an easy and relatively rapid means for cleaning a plurality of tubes or pipes during or within the time in which it would be necessary to expend in cleaning one pipe.

I designates a cleaning device which is designed to be flexibly connected with a source of supply of steam or compressed air and which is adapted to be moved up and down through the several cleaning openings adjacent said pipes. Said device I may be provided with a suitable nozzle *i* adapted to discharge the air or steam onto said ribbed pipes to remove the material collected thereon.

The feed water entering at the top of pipe B′ passes downwardly therein through connection C and upwardly in pipe B^2 and this up and down course is continued until the water passes successively through each pipe and is discharged from pipe B^{14}. Throughout such course the water is subjected to the action of a relatively extensive heating surface since the exterior portions of all the pipes, connections and the bearing portion A are subjected to the action of the products of combustion and therefore the water is quickly and effectively heated prior to its admission to the boiler. The gases or steam which may accumulate in the heater will rise in the several pipes and will pass into the channels to which the pipes are connected and the several by-passes will afford ready escape of such confined gases to the outlet B^{14} and the course of the water will not be impeded or retarded in any way. In order to avoid short circuiting of the course of the water as a result of the presence of these by-passes the latter are relatively reduced in size with respect to the channels, between which they establish communication, therefore while the water is free to run through these by-passes only a relatively small quantity of water can be accommodated by them and therefore the efficiency of the heater is in no way impaired by the presence of these by-passes.

As hereinbefore stated the feed water is heated by the waste gases or products of combustion that pass out the chimney and as shown the device of my invention is disposed in a chamber J through which the products of combustion may pass if desired. In this arrangement the structure A acts as a supporting body and the pipes depend therefrom, however I do not wish to be limited to this specific arrangement. As shown in Fig. 2 the walls of the chamber J are provided with projections *j* and the supporting body A is constructed in a manner to seat on said projection and close the upper end of said chamber.

I claim:—

1. A feed water heater comprising in combination, a body structure provided with a plurality of cleaning openings and a plurality of pipe connecting channels, by-passes connecting said channels, and a plurality of ribbed pipes or tubes connected with each other and secured to said body structure in communication with said channels, the disposition of said pipes being such that a plurality thereof are closely grouped about each opening.

2. A feed water heater comprising in combination, a supporting structure provided with a plurality of cleaning openings and a plurality of pipe connecting channels, by-passes connecting said channels, a plurality of ribbed pipes or tubes depending from said structure and connected with each other and in communication with said channels, a plurality of said pipes being grouped about each opening in close proximity thereto, and a cleaning device adapted to be inserted through any one of said openings to clean the exterior portions of the plurality grouped about the used opening.

3. A feed water heater comprising in combination, a body structure provided with a plurality of pipe connecting channels serially arranged to provide a serial course for the feed water from a point of ingress to a point of egress, by-passes connecting said channels to provide a short circuit egress for the confined gases therein, and a plurality of ribbed pipes or tubes communicating with said channels and connected with each other to form with said channels a complete serial course for the water from the point of ingress to the point of egress, said structure being provided with a plurality of cleaning openings and a plurality of said pipes being grouped about each opening in close proximity thereto in a manner to be accessible to a cleaning device inserted through any one of said openings.

In testimony whereof I affix my signature in presence of two witnesses.

RICHARD KABLITZ.

Witnesses:
MAX DYMSCHÜ,
LAURANCE HILL.

DEFENDANT'S EXHIBIT E.

E. H. FOSTER.

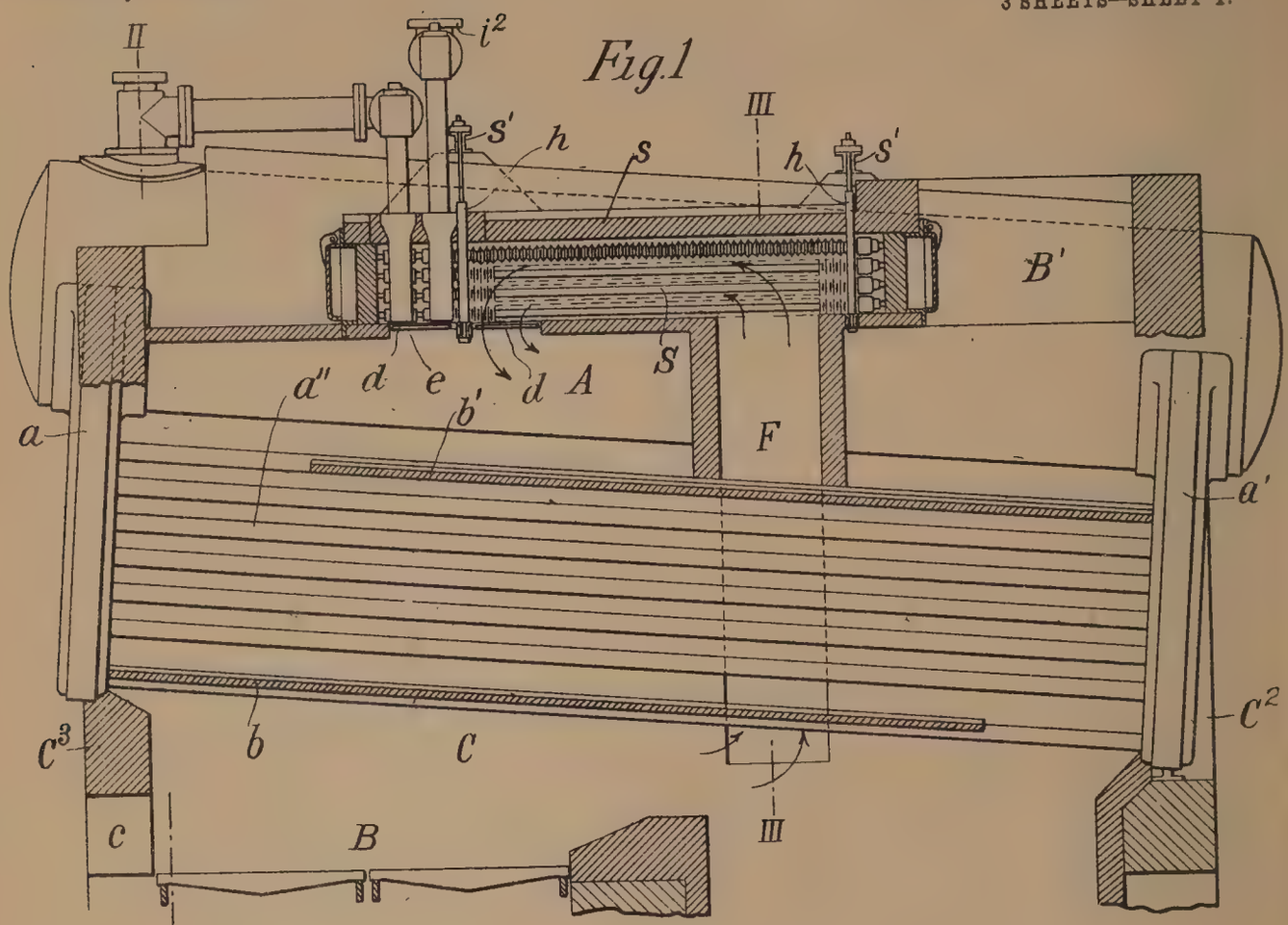
STEAM SUPERHEATER.

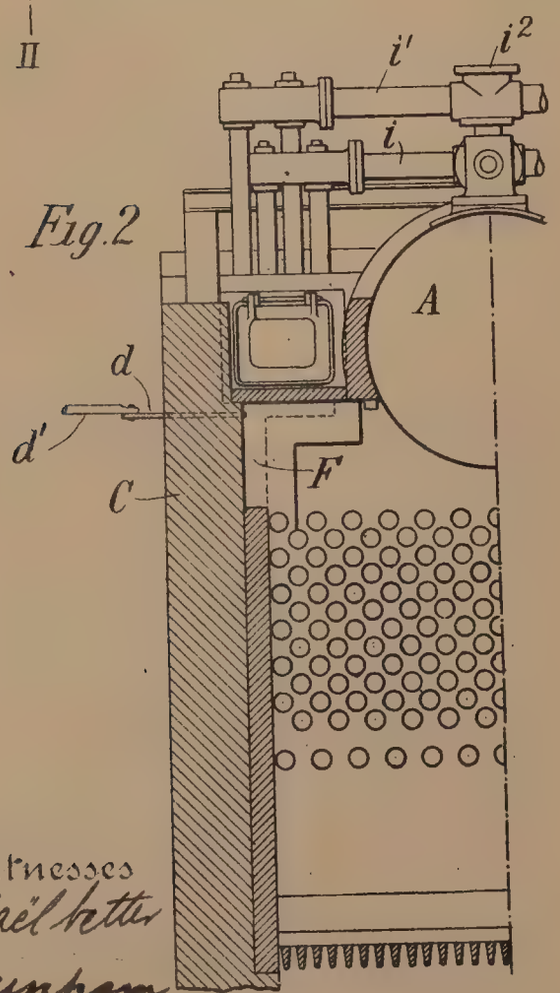
APPLICATION FILED APR. 13, 1906.

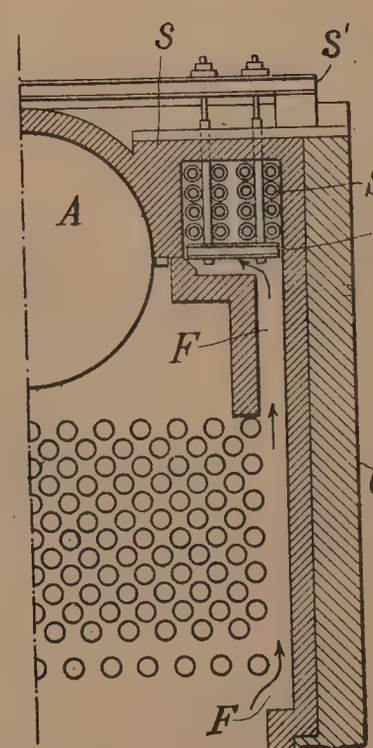
963,732.

Patented July 5, 1910.

3 SHEETS—SHEET 1.







Witnesses
Raphaël Netter
S.S. Dunham

Inventor
Ernest H. Foster
By his Attorneys
Kerr, Page & Cooper

E. H. FOSTER.

STEAM SUPERHEATER.

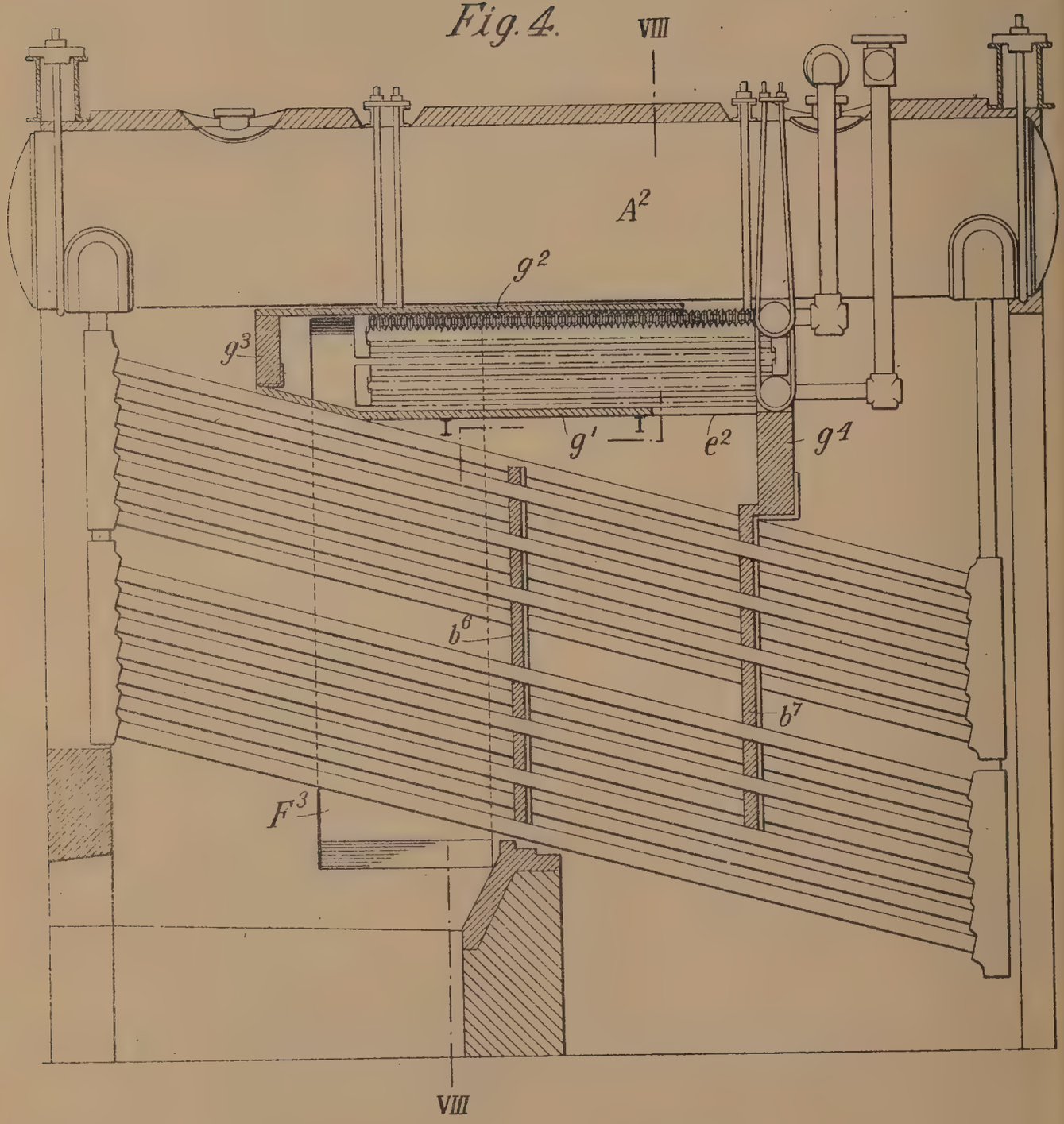
APPLICATION FILED APR. 13, 1906.

963,732.

Patented July 5, 1910.

3 SHEETS—SHEET 2.

Fig. 4.



Witnesses
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A. S. Dunham.

Ernest H. Foster, Inventor
By his Attorneys
Kerr, Page & Cooper

E. H. FOSTER.

STEAM SUPERHEATER.

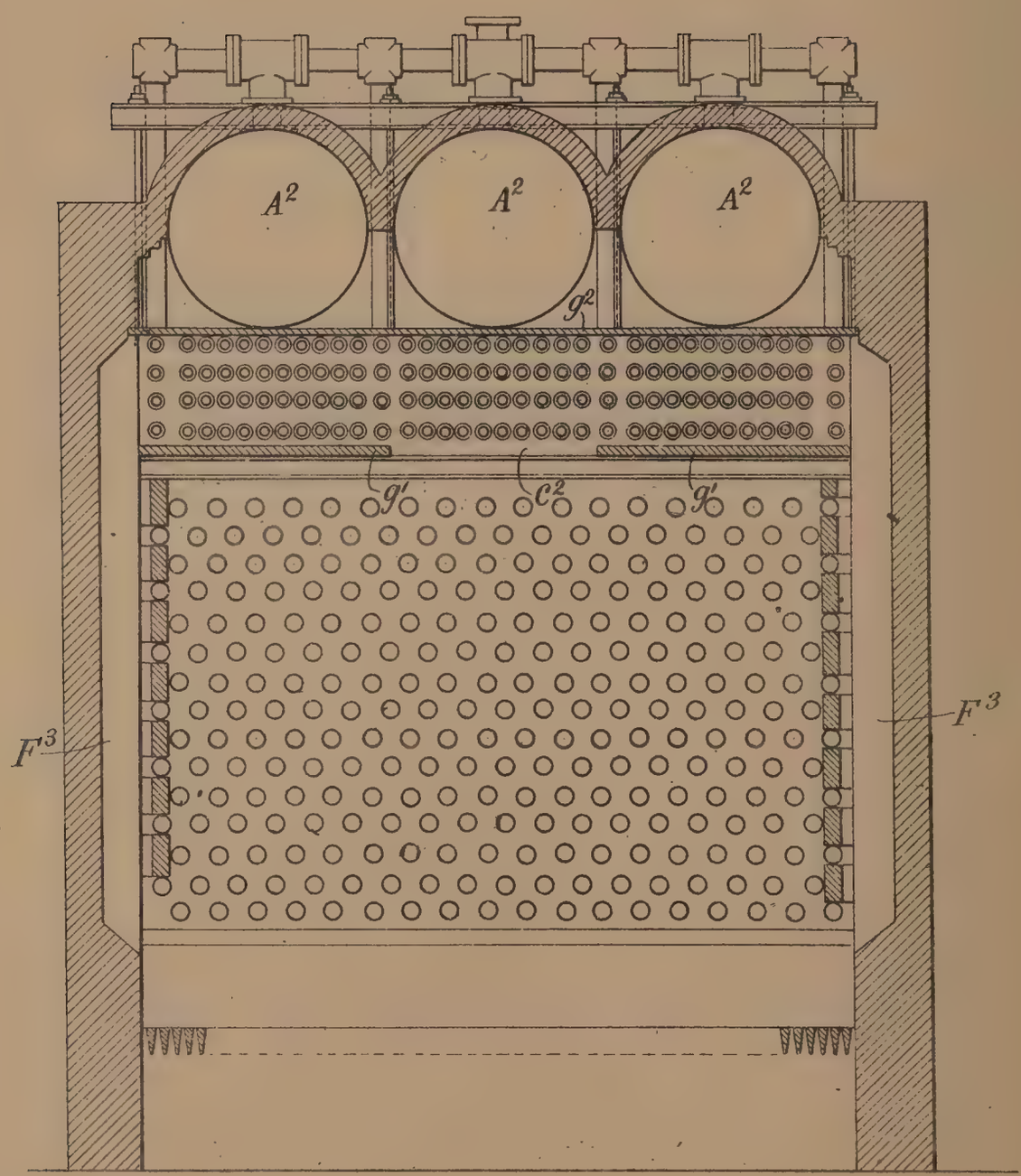
APPLICATION FILED APR. 13, 1906.

963,732.

Patented July 5, 1910.

3 SHEETS—SHEET 3.

Fig. 5.



Witnesses
Raphaël Netter
A. L. Dunham

Ernest H. Foster, Inventor

By his Attorneys
Kerr, Page & Cooper

UNITED STATES PATENT OFFICE.

ERNEST H. FOSTER, OF NEW YORK, N. Y.

STEAM-SUPERHEATER.

963,732. Specification of Letters Patent. Patented July 5, 1910.

Application filed April 13, 1906. Serial No. 311,444.

To all whom it may concern:

Be it known that I, ERNEST H. FOSTER, a citizen of the United States, residing at New York, in the county of Richmond and State of New York, have invented certain new and useful Improvements in Steam-Superheaters, of which the following is a specification, reference being had to the drawings accompanying and forming part of the same.

In a certain class of superheaters the hot gases from the fire box are brought directly to the superheater chamber, in order that as little of the heat as possible may be abstracted from said gases before reaching the superheater.

My present invention is an improvement in devices of this general class and in its preferred form consists in the provision of flues or passages preferably located in the side walls of the boiler setting for conducting the superheating gas from the furnace to one end of the superheater chamber, and in the arrangement of a direct passage of communication from the opposite end of the superheater chamber to a point between a part of the boiler and the chimney, whereby the natural draft is made available to carry uncooled gases through the superheater chamber in a more effective manner than has heretofore been accomplished by the devices in use.

The invention involves also other details which will be described by reference to the annexed drawing.

Figure 1 is a side elevation of a water tube boiler, the setting being in section, showing a superheater section and the flue or passage for conveying to it hot gases from the furnace. Figs. 2 and 3 are cross sections on lines II.—II. and III.—III., respectively, of Fig. 1. Fig. 4 is a side elevation of another type of water tube boiler, showing the superheater and one of the flues therefor. Fig. 5 is a section on line VIII.—VIII. of Fig. 4.

Referring now more particularly to Figs. 1, 2 and 3, I indicates the drum of the boiler. Depending therefrom are the water legs a, a', between which are the water tubes a''. B is the furnace grate, and above the same, extending rearwardly from the front water leg a, is a baffle plate b, located above the lowermost series of water tubes. Extending forwardly from the rear leg a', above the uppermost series of tubes, is a baffle b'. The course of the furnace gases is therefore rearward under the drum A to the stack opening B'. The boiler is mounted in the usual setting, having side walls C, C', a rear end wall C^2, and front wall C^3, the latter having the customary opening c for the furnace door. The superheater is constructed in two sections or parts, mounted on opposite sides of and about on a level with the drum A. One of the superheater sections is shown at S. The superheater sections are inclosed by suitable brick or tile work, as s, and are supported by hangers h of U-shape depending from cross beams s' extending transversely over the drum A. At the forward ends of the superheater chambers are hinged closers s^2, by which the superheater sections may be conveniently reached for cleaning, etc. One set of the front headers is connected with a pipe i, carrying steam to them from the drum A, while the other set of front headers is connected with an outlet pipe i', to deliver the superheated steam to the service main, connected to the coupling i^2. Beginning at a point to the rear of the grate B below the baffle b, and extending vertically to and discharging into the superheater casing or setting, is a flue or passage F. This flue is open to the furnace below the baffle b, so that it will receive gases of very high temperature. The gases received by the flue are carried thereby into the superheater chamber at the rear end thereof, and pass forward through the chamber to the exit opening e, from which they flow into the current of gases to the stack. The superheater is thus supplied with gases of high temperature, no matter how much heat the boiler may take from the current passing around the tubes and baffle plates. The superheater flue is preferably made in the side wall of the boiler setting, a flue being provided for each superheater section, as shown clearly in Figs. 2 and 3. For the purpose of regulating the flow of gases through the superheater chambers, the outlet openings thereof may be provided with dampers, one of which is shown at d, operated in any convenient way, as by a rod d' extending outside of the setting.

In the arrangement illustrated in Figs. 4 and 5, the superheater is located close to the drums A^2, so as to leave sufficient space above the vertical baffle b^6 for the free passage of the furnace gases. The superheater is inclosed by a bottom plate g', a top plate

g^2, and a front end-wall g^3. The top and bottom plates extend from side to side of the boiler setting, and rearwardly to the cross wall g^4, in and by which the rear headers of the superheater are supported. At the center of the rear end of the bottom plate is an exit opening e^2. As in the case just described above, the superheater flues F^3 extend from the rear of the grate and discharge into the forward end of the superheater casing. The hot gases then flow rearwardly and escape through the outlet opening c^2, where they join the furnace gases flowing downwardly between the vertical baffles b^6 and b^7. In this case also, the flow of gases may be controlled by one or more dampers, not shown.

Numerous other embodiments of the invention might be illustrated, but those already described are sufficient to show clearly the essential principle of the invention, whereby the superheater is supplied with furnace gases which have given up substantially none of their heat to other elements of the plant.

It will be clear to the skilled engineer who undertakes to apply my invention in practice that it may be utilized in a great variety of ways without departure from its proper scope.

What I claim is:

1. The combination with a boiler setting and furnace, and a water tube boiler having its water tubes arranged in the path of the furnace gases flowing through said setting, of a superheater located above the water-tubes, and one or more flues or conduits in the side walls of the setting, extending from the furnace and discharging hot gases therefrom upon the superheater, as set forth.

2. The combination with a boiler setting and furnace, and a water-tube boiler having its water tubes arranged in the path of the furnace gases flowing through the setting, of a superheater casing within the setting and above the water tubes, and one or more flues or conduits in the side walls of the setting, extending to the said casing from the furnace, said casing having an outlet opening arranged to discharge into the current of gases flowing through the setting, as set forth.

3. The combination with a boiler setting and furnace, and a water tube boiler having its water tubes arranged in the path of the furnaces gases flowing through the setting, of a superheater chamber in proximity to a side wall of the setting and above the water tubes, a superheater inclosed by the chamber, and one or more flues in the said side wall of the setting extending upwardly from the furnace and discharging hot gases therefrom upon the superheater, as set forth.

4. The combination with a boiler setting and furnace, and water tube boiler having its water tubes arranged in the path of the furnace gases flowing through said setting, of a superheater located above the water tubes, a casing inclosing the superheater, and one or more flues or conduits in a side wall of the setting, extending from the furnace to one end of the casing, said casing having an outlet opening at its other end arranged to discharge into the current of gases flowing through the setting.

ERNEST H. FOSTER.

Witnesses:
M. Lawson Dyer.
S. S. Dunham.

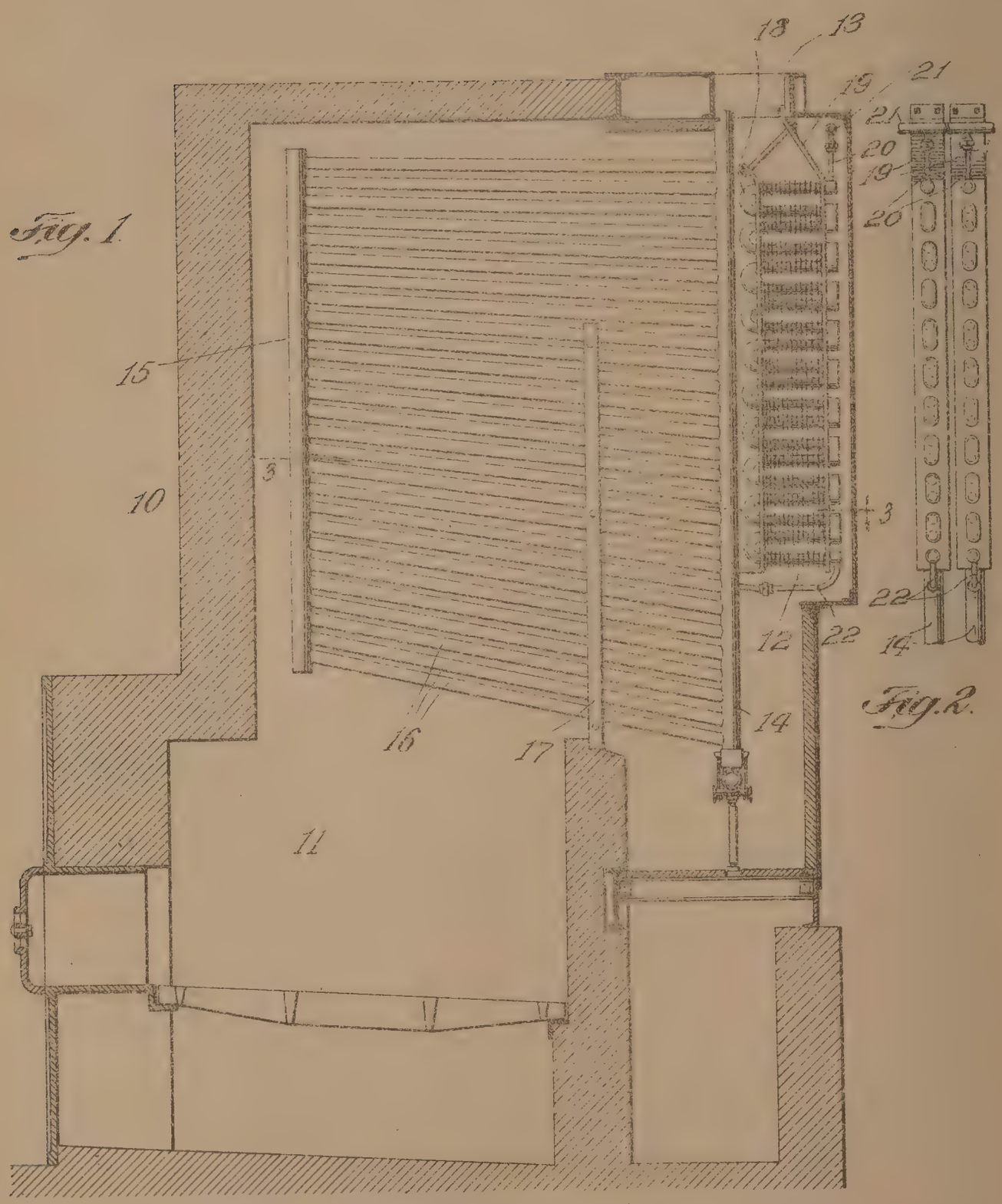
DEFENDANT'S EXHIBIT F.

E. H. FOSTER.

FUEL ECONOMIZER.

APPLICATION FILED FEB. 17, 1916.

1,239,377. Patented Sept. 4, 1917.



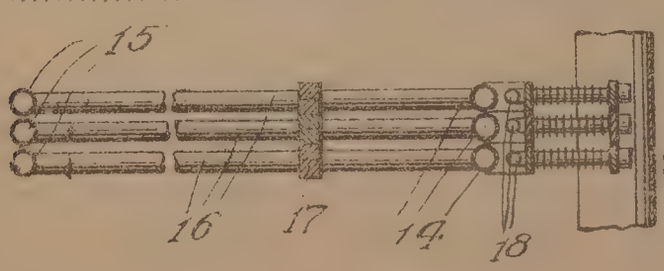


Fig. 3.

Inventor
Ernest H. Foster
By his Attorney
Kerr Page Cooper & Hayward

UNITED STATES PATENT OFFICE.

ERNEST H. FOSTER, OF DONGAN HILLS, NEW YORK, ASSIGNOR TO POWER SPECIALTY COMPANY, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

FUEL-ECONOMIZER.

1,239,377. Specification of Letters Patent. Patented Sept. 4, 1917.

Application filed February 17, 1916. Serial No. 78,799.

To all whom it may concern:

Be it known that I, Ernest H. Foster, a citizen of the United States, residing at Dongan Hills, Richmond county, and State of New York, have invented certain new and useful Improvements in Fuel-Economizers, of which the following is a full, clear, and exact description.

The invention which constitutes the subject matter of this application relates to an economizer, one of the important features of which consists in arranging the economizer so that the feed water is introduced at the top thereof and by aid of its gravity zigzags back and forth across and downward in counter current to the rising gases, the highest temperature of the feed water in said economizer being at the point where it enters the boiler proper.

Another of the more important features of the invention consists in employing independent cast metal rings in contact with each other and fitting snugly on the economizer tubes so that the absorption of heat energy of the gases of combustion by the water flowing through the economizer tubes will be as complete as possible. This means that the heat must pass from the gases to the metal comprising the tube and thence from the metal to the water. The rate of heat transference between a gas and a metal differs from the rate between water and a metal, being much greater in the latter case. In order to compensate for this difference it is necessary to provide a larger contact surface between the gas and the metal, where the transference is slow, than between water and the metal where the transference is relatively rapid. Thus by providing an economizer tube with a large external as compared with internal surface, a higher efficiency or transference capacity is obtained than if ordinary cylindrical wall tubes were used, as has been the custom heretofore.

This construction permits the use of two kinds of metals in making economizer tubes which in turn enables the application of economizers to high steam pressures. Economizer tubes as now commonly employed are made from cast iron because the resistance of the latter to attacks from gases of combustion and from the corrosive or pitting tendency of hot water which passes through the tubes. Cast iron tubes are not reliable unless made with relatively thick walls which implies more weight and requires more space than if a more reliable or stronger metal is used. On the other hand tubes made from the stronger and more reliable metals, such as steel and wrought iron, have proven unsuccessful as economizers because of their short life due to the corrosive effect of gases and water. Then again modern practice is constantly requiring higher steam pressures and up to approximately 200 lbs. per square foot cast iron economizers have been used successfully, but at higher pressures cast iron is unreliable for this purpose, with a result that one is forced to use steel or wrought iron tubes or else abandon the use of economizers entirely, which would not only be a serious loss to power plant economy but necessitates the burning of more fuel. My invention therefore contemplates the use of non-corrodible tubes, such as copper or brass, covered with cast iron external protection surfaces with the beneficial result of the water, which has a corrosive action, coming into contact with a non-corrodible surface forming the body of the tube, and with the further result that the gases of combustion come in contact with the cast iron exterior which has excellent durability or resistance against the detrimental action of said gases.

Another feature of my invention consists in arranging the economizer in sections so that each section is independently removable, or removable with the corresponding boiler section.

In the drawings:

Figure 1 is a cross-section of a boiler construction with my invention embodied therein.

Fig. 2 is an end view of a portion of the economizer tubes.

Fig. 3 is a horizontal view taken on line 3—3 of Fig. 1.

Referring to the drawings in detail the reference numeral 10 designates a type of boiler illustrating one application of my invention this particular type being selected because of its simple construction thus making the invention and its useful application easily comprehended. The boiler setting is provided with a furnace 11, a passage 12 in the rear thereof for the escape of gases from the boiler proper to the chimney 13, and suitable regulating means employed to control the degree of pressure required. The

boiler proper is composed of a plurality of boiler sections each section comprising an inlet header 14, an outlet header 15, and connecting tubes 16. The setting is also provided with a baffle 17 which causes a proper flow of the gases among the boiler tubes as will be understood.

The economizer proper comprises a plurality of vertical sections of tubes 18 located in the passage 12, said tubes being preferably made of copper or brass or other non-corrodible metal and so arranged that the flow of feed water therethrough is back and forth across and downward in a direction opposite to the flow of furnace gases through said passage 12. These sections of tubes are provided with supports 19, with inlets 20, a feed water pipe 21 connected to said inlets, and connections 22 to the inlet header 14.

The tubes 18 are provided with a cast metal covering preferably in the form of a series of independent, continuous cast metal tapered rings in contact with each other which are employed as a protection for the tubes and to absorb additional heat energy from the waste gases from the furnace.

The arrangement of the economizer tubes in zig-zag fashion so that the flow of feed water is to and fro across the passage 12 results in a gravity feed of the feedwater through the economizer tubes into the inlet header of the boiler, and this horizontal arrangement, furthermore, avoids the development of air pockets in said economizer tubes. Any section may be removed for the purpose of repair or replacement without disturbing other sections. This removal of a section is also desirable when a corresponding section of the boiler tubes requires removal. when they may be removed together.

From the above description it will also be seen that I have devised a simple form of economizer for boilers which is not only capable of withstanding the corrosive action of the water on the interior thereof but also capable of withstanding the corrosive action of the gases of combustion on the exterior thereof. Furthermore, my invention also embodies the economical feature of an economizer composed of two metals which are constructed and arranged to compensate for the relatively different rates of heat transference between the gases of combustion and the tube on the one hand and the tube and feed water on the other hand. The use of the two metals mentioned, or their equivalents, in the construction of the tubes and in the manner indicated lessens the cost of the metals over the cost of the ordinary economizer tubes and at the same time there results not only a lighter tube, that is, one containing less metal, but a tube for the purpose which is materially stronger than the tubes now in vogue.

It will be understood that I do not limit myself to the exact construction and composition of parts shown and described as the drawing is merely an illustrative one and the invention is capable of other embodiments without deviating from the true spirit and scope of my invention.

What I claim is:

1. A boiler having a plurality of individual boiler sections comprising headers and boiler tubes connecting said headers and also having a vertical passage for the furnace gases beyond said section, in combination with an economizer composed of a plurality of individual sections vertically arranged in said passage and installed between the boiler and smoke stack, the tubes of said economizer being vertically arranged with respect to the flow of the furnace gases and the inlet and outlet to said economizer being at the top and bottom respectively, whereby water circulates by aid of its own gravity through said economizer, said economizer sections being individually connected to said boiler sections whereby one boiler section and one economizer section may be removed for repair or replacement without disturbing the other sections.

2. A boiler comprising a plurality of boiler sections and a vertical passage for the escape of furnace gases located in the rear of said sections, in combination with an economizer vertically arranged in said passages and consisting of a plurality of sections each individually connected to said boiler sections and each individually removable with one of said boiler sections.

In testimony whereof I hereunto affix my signature.

ERNEST H. FOSTER.

DEFENDANT'S EXHIBIT G.

W. F. KEENAN, Jr. & D. D. THOMAS.

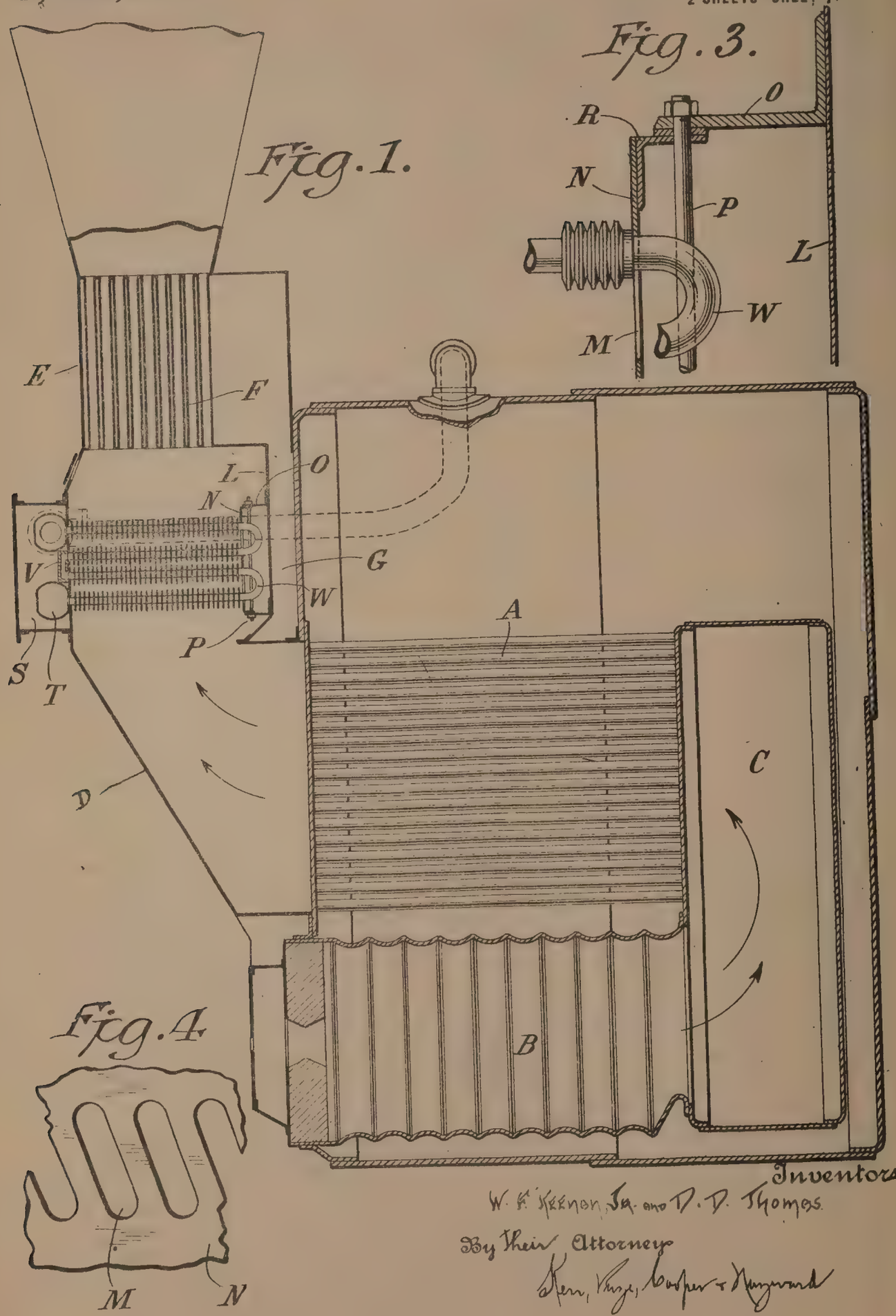
SUPERHEATER FOR MARINE BOILERS.

APPLICATION FILED APR. 24, 1917.

1,282,851.

Patented Oct. 29, 1918.

2 SHEETS—SHEET 1.



W. F. KEENAN, Jr. & D. D. THOMAS.

SUPERHEATER FOR MARINE BOILERS.

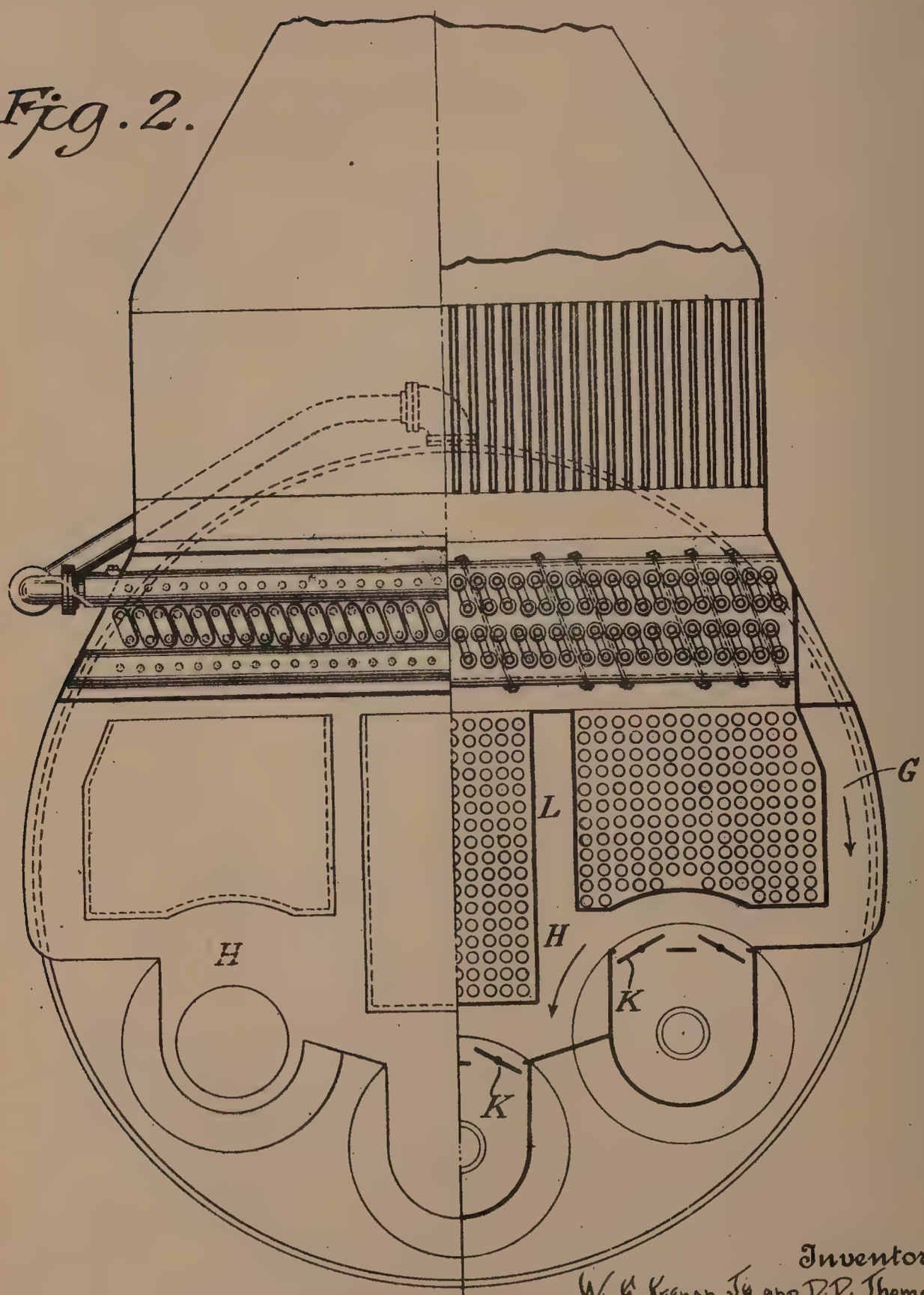
APPLICATION FILED APR. 24, 1917.

1,282,851.

Patented Oct. 29, 1918.

2 SHEETS—SHEET 2.

Fig. 2.



Inventors

W. F. Keenan, Jr. and D. D. Thomas.

By their Attorneys

Kerr, Page, Cooper & Hayward.

UNITED STATES PATENT OFFICE.

WALTER F. KEENAN, JR., OF NEW YORK, N. Y., AND DAVID D. THOMAS, OF BALTIMORE, MARYLAND, ASSIGNORS TO POWER SPECIALTY COMPANY, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

SUPERHEATER FOR MARINE BOILERS.

1,282,851. Specification of Letters Patent. Patented Oct. 29, 1918.

Application filed April 24, 1917. Serial No. 164,116.

To all whom it may concern:

Be it known that we, WALTER F. KEENAN, Jr., and DAVID D. THOMAS, both citizens of the United States, residing, respectively, at New York, in the county and State of New York, and at Baltimore, and State of Maryland, have invented certain new and useful Improvements in Superheaters for Marine Boilers, of which the following is a full, clear, and exact description.

Certain forms of marine boilers are provided with air heater tubes, which generally described, are tubes in the flue or stack through which pass the heated products of combustion and which are utilized to impart heat to the air for combustion forced around them and carried by means of ducts to the furnace. Boilers equipped with this device have certain peculiarities of construction which have to be taken into consideration in case it be desired to add to them a steam superheater.

This problem we have solved by the construction and arrangement of a superheater upon which is based our present application and which, in general terms, may be described as a superheater extending entirely across the uptake between the boiler and the air heater tubes, and supported from a vertical partition wall in the rear part of the uptake at such a distance from the boiler tube sheet as to form a passage from the air heater tube chamber to the fire box. The front of the superheater is secured to the front wall of the uptake or to a plate secured over an opening therein.

This general plan of construction and the details of construction necessary for carrying it into effect are shown in the accompanying drawings in which—

Figure 1 is a vertical longitudinal sectional view of a boiler equipped with our improvement.

Fig. 2 is a part elevation and part cross-sectional view of the same.

Fig. 3 is an enlarged detail view of the means of supporting the superheater elements from the aforesaid partition.

Fig. 4 is an enlarged detail of a part of a supporting plate secured to said partition.

The boiler represented is one adapted to burn an oil fuel and comprises a set of boiler tubes A, a furnace B, and a chamber C for the products of combustion from which they pass through the tubes A to the uptake D.

Between the latter and the stack are a series of air heater tubes E through which the waste products of combustion pass, and these are arranged in a compartment or passage F through which air is drawn or forced over or around the hot tubes and directed through the passage G into the inclosed space H, from which it is forced through adjustable doors or dampers K into the furnace. This is a well known type of boiler and is modified to meet the requirements of the present invention only in the provision of the supporting diaphragm or plate L for the rear ends of the superheater.

The superheater, preferably of the now well known Foster type, is located in the uptake above the boiler tubes and beneath the air heater tubes, and extends across substantially the whole of this space, so as to receive the maximum absorption of heat without sensibly interfering with the draft. The rear bends W of the superheater elements pass through inclined slots M in a plate N which is removably secured to brackets O on the diaphragm plate L by bolts P passing through the brackets and angle plates R on the said plate N. This supports the rear end of the superheater and protects the bends from the direct action of the hot gases.

The ends of the superheater tubes at the front pass through the wall of the uptake into a compartment S where they are connected with the headers T or cross connections V.

The details of the structure as a whole are not shown further than is necessary to illustarte the general plan of construction and operation of the same, and the part played by the superheater.

The special means for securing the latter in position by the slotted plate at one end and the wall of the uptake at the other so that the ends of any element may be disconnected from the wall and the plate removed to release the bends, is not claimed in this application as a part of our invention.

What we claim is:—

1. In a steam boiler equipped with air heater tubes in its flue, the combination

with the said tubes of a partition or diaphragm secured in the flue at such distance from the rear wall as to form a passage-way for the heated air to pass on its way to the fire box, a plate removably secured to brackets and in proximity to such partition, and a superheater the bends of the straight tubes of which are supported in slots in the said plate and the front ends of which pass through the flue wall, the said tubes extending entirely across the flue under the air heater tubes and in line with the greater dimension of the space therefor, as set forth.

2. In a steam boiler equipped with air heater tubes in its flue, the combination with the said tubes of a partition or diaphragm secured in the flue at such a distance from the rear wall as to form a passage-way for the heated air to pass on its way to the fire box, brackets secured to said partition, a plate removably secured to said brackets, and a superheater the tubes of which extend across the flue, having its bends at the rear supported in slots in said plate and its rear ends secured in the flue wall and projecting through the same for connection with headers and connections in a compartment outside the same.

In testimony whereof we hereunto affix signatures.

WALTER F. KEENAN. Jr.
DAVID D. THOMAS.

DEFENDANT'S EXHIBIT H. 1303

Etats-Unis

Republique Française.

Ministère Du Commerce Et De L'Industrie.

Direction De La Propriété Industrielle.

Copie officielle d'un brevet d'invention délivré sous le no 237.583.

Mémoire descriptif annexé au brevet d'invention de quinze ans pris le 7 Avril 1894 par la Societé de Dietrich et Cie représentée par Mr. Wolff, 37 bd Magenta a Paris

et qui lui a été délivré par arrêté du Ministre du Commerce, de l'Industrie, des Postes des Télégraphes en date du 25 1304
Juin 1894, pour "Chandiéres á eau ou á vapeur avec Auyaux à ailettes"

Copie du brevet No 237.583 du 7 Avril 1894 pour "Chaudières à eau ou à vapeur avec "tuyaux à ailettes" par la Société de Dietrich et Cie

Les tuyaux à ailettes peuvent etre employés comme chaudières à eau ou à vapeur, si on les dispose en batteries, les uns à coté des autres et les uns sur les autres, pour en former un groupment présentant à la flamme ou aux fumées desquelles la chaleur est à utiliser, l'étendue de surface de chauffe voulue; et si l'on fait en sorte que l'eau à chauffer 1305
circule à l'intérieur de ces tuyaux du point le plus bas au point le plus élevé du groupement. Ces tuyaux à ailettes permettront alors de réunir sous un très faible volume une surface de chauffe considérable et de disposer ces chaudières dans un espace trés restreint.

Pour assurer encore la canalisation et l'égale répartition de la fumée à travers le groupement de ces tuyaux à ailettes, et isoler leurs joints nombreux du courant des fumées, parsuite éviter de bruler les joints, nous pouvons encore faire

1306 venir, sur ces tuyaux à ailettes des ailettes spéciales plus grandes, de forme rectangulaire A, B, C planches I, II, III, servant de cloisons canalisant la circulation des fumées à travers le groupement et obligeant ces fumées à circuler en montant puis en descendant. Quant aux joints des tuyaux entre eux, ils seront ramenés horizontalement par la forme en double T couché que nous adoptons pour ces tuyaux à ailettes; et leurs joints horizontaux seront protégés par les grandes ailettes rectangulaires B et C qui disposées vers les extrémités des dits tuyaux à ailettes formeront écrans de protection des joints en maintenant le courant des fumées hors des joints. Naturellement ces grandes ailettes spéciales A,
1307 B et C devront etre de grandeur telle qu'elles viennent toucher en hauteur et en largeur les grandes ailettes correspondantes des tuyaux voisins de dessus, de dessous, de droite et de gauche.

Les dessins ci-joints représentent le groupement de nos tuyaux à ailettes dans l'application de ces tuyaux:

la planche I à une chaudière à eau,

la planche II à une chaudière à vapeur,

la planche III au réchauffeur d'eau d'alimentation d'une chaudière à vapeur, ce réchauffeur disposé à la suite de la susdite chaudière, dans les fumées qui se ren-
1308 dent de cette chaudière à la cheminée.

Ces appareils ne sont indiqués que pour mieux faire saisir la réalisation pratique de l'emploi des tuyaux à ailettes et celui de l'emploi de tuyaux à ailettes pourvus des ailettes spéciales A, B et C canalisant la fumée dans son parcours à travers le groupement des tuyaux formant chaudière, et protégeant leurs joints, et pour montrer l'utilisation des chaudières ainsi obtenues au chauffage de l'eau ou à la production de la vapeur; mais il est bien évident que d'autres formes et dispositions diverses dans l'ensemble ou les détails de ces

appareils peuvent etre données pour répondre aux commodités d'installation. 1309

Les tuyaux à ailettes ordinaires, de meme que les tuyaux à grandes ailettes spéciales, A, B, C, employés dans ces appareils seront généralement en forme de double T couché, mais nous réservons aussi de pouvoir leur donner la forme habituelle des tuyaux à brides aux extrémités. Ces tuyaux se raccorderaient alors les uns aux autres par des coudes doubles ou à 180° dans leur groupement formant chaudière.

Par la présente demande de brevet d 'invention pour quinze ans, nous désirons nous assurer la propriété exclusive: 1°– de la fabrication des tuyaux en fonte, en fer ou en fer et fonte, à grandes ailettes spéciales A, B et C, canalisatrices 1310 de la fumée et protectrices des joints des tuyaux et 2° celui de l'application de ces tuyaux à grandes ailettes spéciales A, B et C et encore celle de l'application de tuyaux et ailettes ordinaires aux chaudières à vapeur, à eau, aux réchauffeurs d'eau d' alimentation de chaudières et en général à tous appareils chauffant réchauffant des liquides ou des vapeurs.

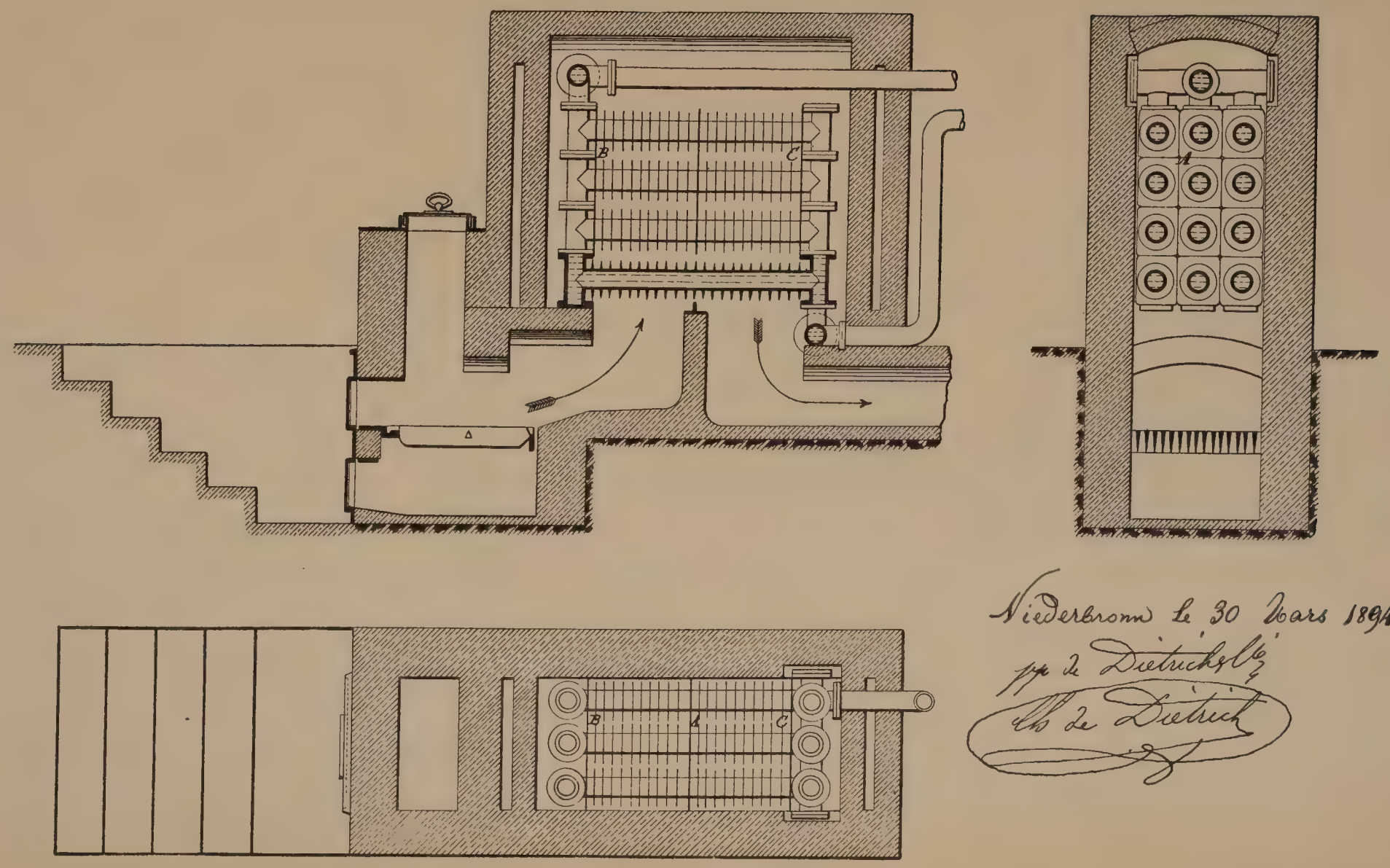
Par Procuration de

DIETRICH & CIE

Signé: Ch. de Dietrich.

[MEMO. Bound here in original are the certificates of 1311 United States Secretary of State and United States Vice-Consul of Paris, France, Ministere du Commerce, Ministere du Commerce et de l 'Industrie and Le Ministre des Affaires Etrangeres.]

CHAUDIÈRE A EAU.

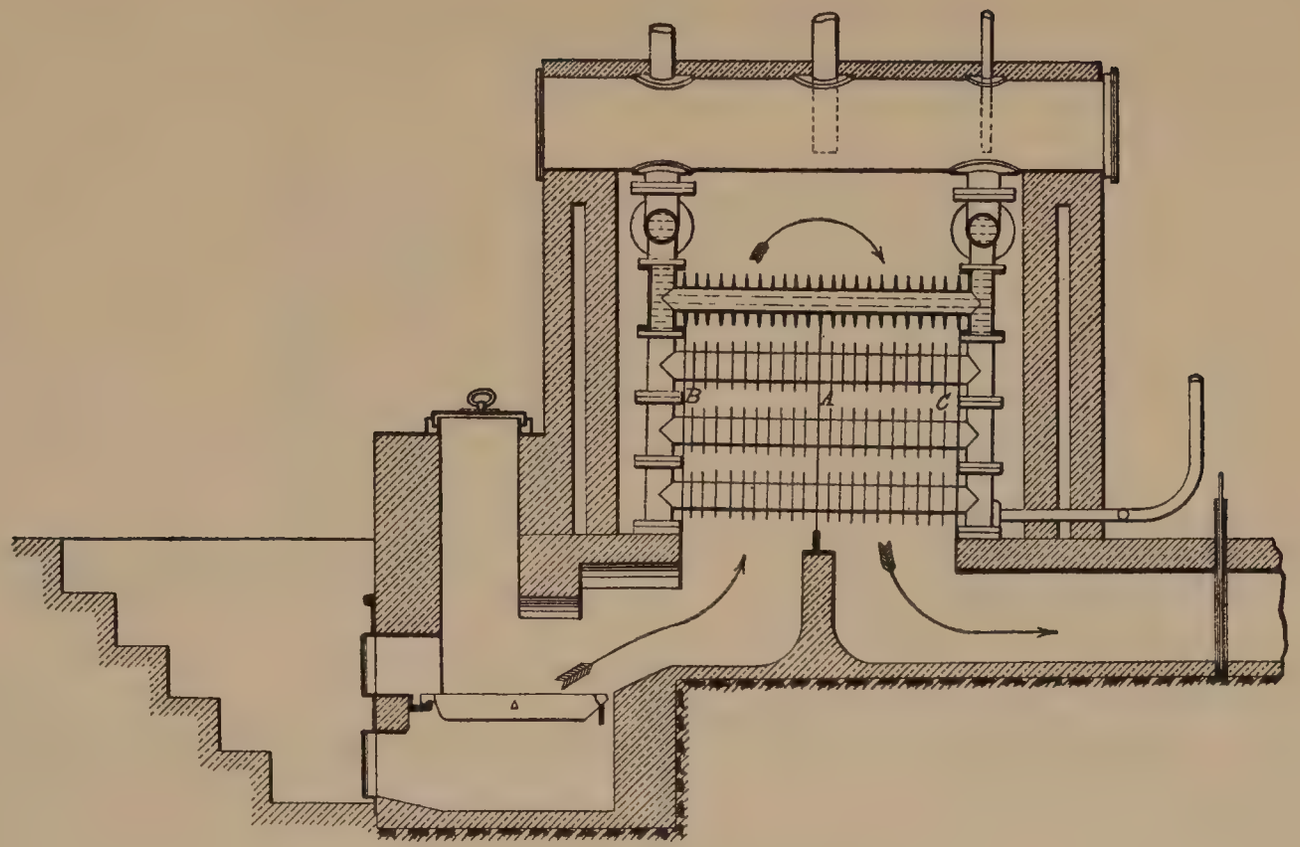


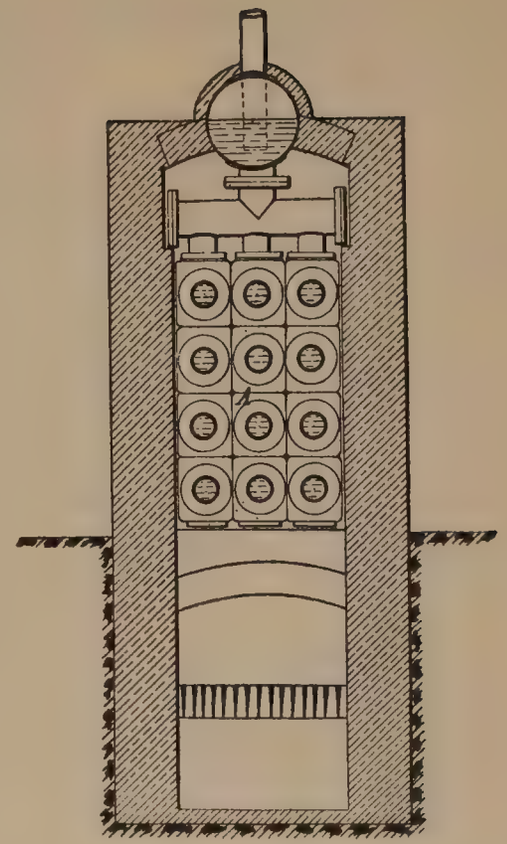
Niederbronn le 30 Mars 1894

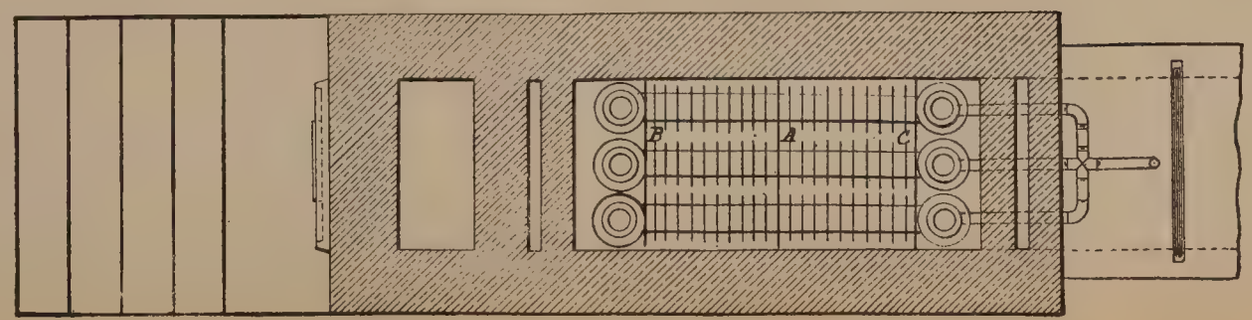
pp de Dietrich & Cie

Ch de Dietrich

CHAUDIERE A VAPEUR







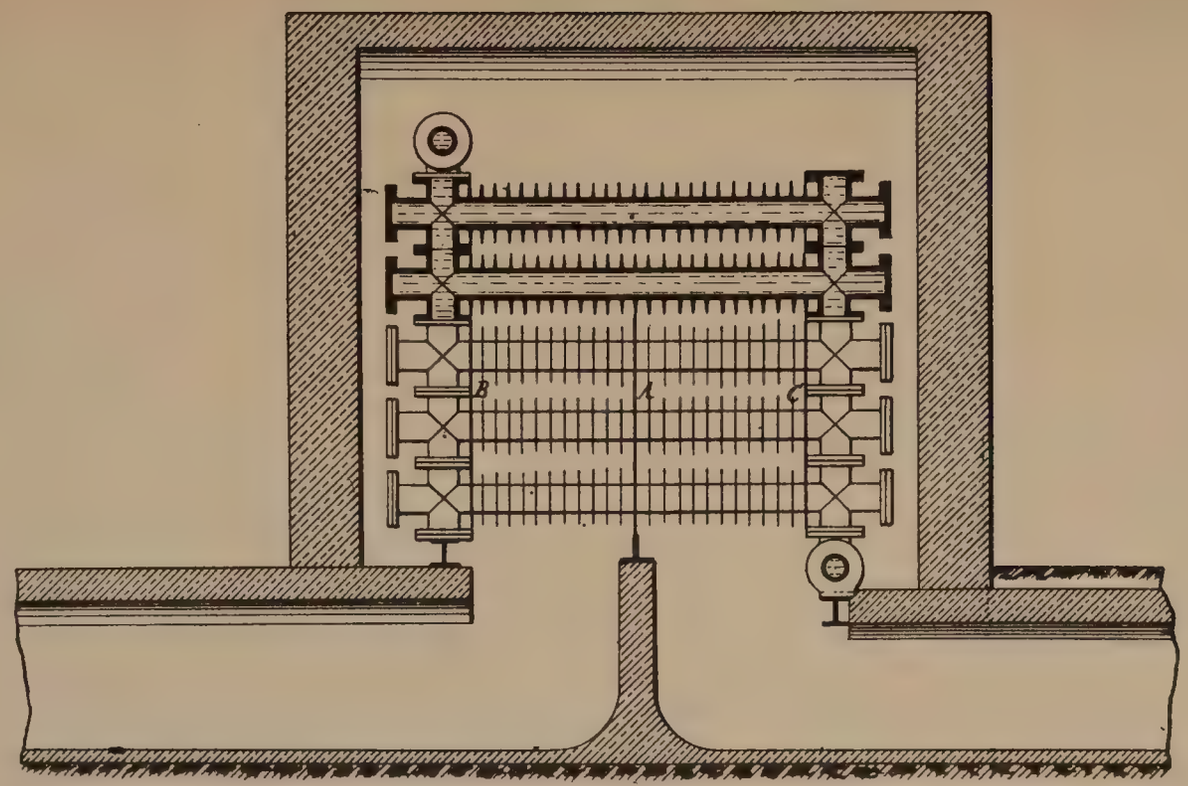
Niederbronn le 30 Mars 1894

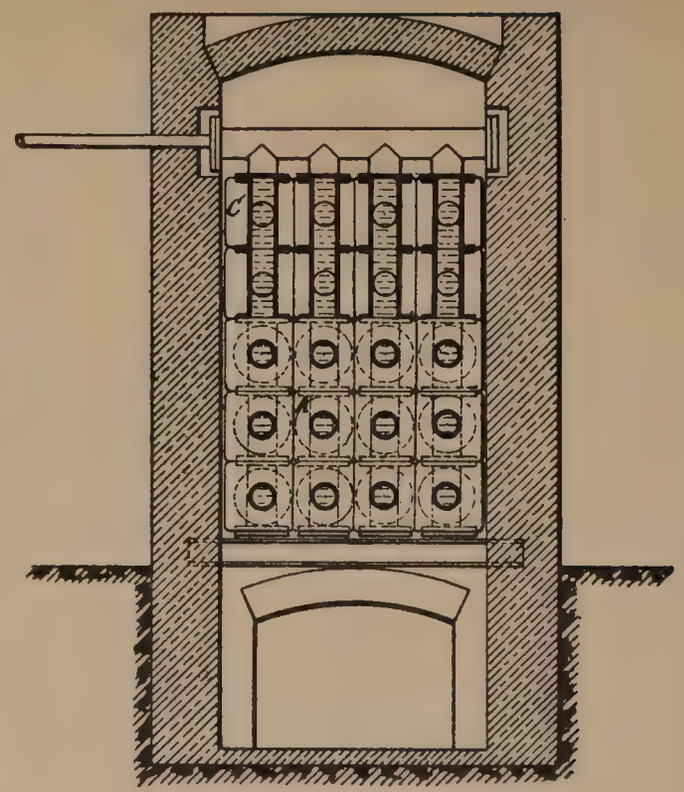
pp de Dietrich & Cie

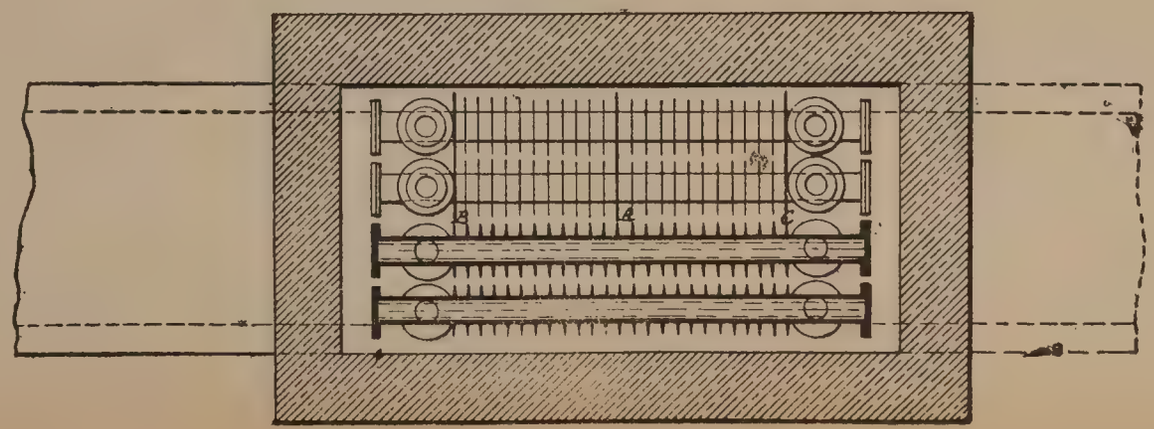
Ch de Dietrich

RECHAUFFEUR D'EAU D'ALIMENTATION D'UNE CHAUDIERE

A VAPEUR







Niederbronn le 30 Mars 1894

pp. de Dietrichs Ets

Ch. de Dietrich

DEFENDANT'S EXHIBIT I (TRANSLATION). 1333

FRENCH REPUBLIC

MINISTRY OF COMMERCE AND INDUSTRY

MANAGEMENT OF INDUSTRIAL PROPERTY

Official Copy of Letters Patent Delivered Under the Number 237,583

Descriptive memoir annexed to Letters Patent for fifteen years from April 7, 1894 for the Society de Dietrich & Co. represented by Mr. Wolff, 37 Boulevard Magenta in Paris

and which has been delivered to it by decree of the Minister of Commerce, Industry, Posts, and Telegraphs 1334
under date of June 25, 1894, for "Boilers for Water or Steam with Pipes having Disks"

Copy of Patent No. 237,583 of April 8, 1894 for "Boilers for Water or Steam with "Pipes having Disks" to The Society of Dietrich & Co.

Tubes provided with disks may be used for water heaters or boilers if one arranges them in groups side by side or one above the other, forming an arrangement which presents to the flame or to the hot gases, whose heat is to be absorbed, the desired amount of heating surface; and if one arranges them in such way that the water to be heated circulates in- 1335
side the tubes from the lowest point to the highest. Such disked tubes will permit the assembly of a very considerable heating surface in a small volume and permits the arrangement of boilers in very restricted space.

In order to provide circulation and uniform distribution of the hot gases across the group of disked tubes, and in order to protect the numerous joints from the gases so as to avoid burning of the joints, we provide on the tubes special large disks of rectangular form, A, B, C, Figs. I, II, III,

1336 which confine the circulation of the gases across the group and enforce a path which first is ascending and then descending. As to the joints between the tubes, they will be arranged horizontally in the form of a cross, which we adopt for these disked tubes; and their horizontal joints will be protected by the large rectangular disks B and C, which, being provided near the extremities of the said disked tubes, will form protecting screens for the joints and keep the current of hot gas away from the joints. Naturally the large special disks A, B, and C will have a size such that they touch both above and below and on their sides the corresponding large disks of the neighboring tubes above and
1337 below, on the right and at the left.

The accompanying drawings represent the arrangement of disked tubes in certain applications.

Figure 1 shows a water heater, Figure 2 a steam boiler, Figure 3 an economizer arranged in sequence to the above mentioned boiler in the gases which go from that boiler to the chimney.

These pieces of apparatus are indicated merely to show the practical form of the use of disked tubes and of the use of tubes provided with the special disks A, B and C, confining the gases in their path across the group of tubes forming
1338 the boiler and protecting their joints, and also to show the utilization of boilers so obtained for heating water or for the production of steam, but it is quite evident that other forms and arrangements in assembly or in the details of these pieces of apparatus may be used in order to meet the convenience of installation.

–2–

The usual disked tubes, as well as the tubes with special large disks A, B and C used in these pieces of apparatus, will commonly have the form of a cross at their ends, but we

reserve also the right to give them the usual flange form at the ends. In this case, the tubes would be connected by 180 degree bends when grouped to form a boiler. 1339

In the present request for a patent for fifteen years, we desire to obtain the exclusive right, first, to the fabrication of cast iron, wrought iron, or cast iron and wrought iron tubes with large special disks A, B and C confining the gases and protecting the joints of the tubes with large special disks, A, B and C; and furthermore, the application of ordinary disked tubes to steam boilers, water heaters, economizers for boiler feed water, and in general for all heating apparatus used for heating liquids or vapors.

1340

By Authority

DE DIETRICH AND COMPANY

(Signed) Ch. de Dietrich

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1341

[Second Edition.]

N° 7733 A.D. 1908

Date of Application, 7th Apr., 1908
Complete Specification Left, 7th Oct., 1908—Accepted, 18th Mar., 1909

PROVISIONAL SPECIFICATION.

"Improvements in and relating to Water Tube Boilers."

I, JOHN PROTHERO DAVIES, of 19, Fawe Park Road, Putney, in the County of London, Engineer, do hereby declare the nature of this invention to be as follows:—

My invention relates to that type of water tube boiler in which horizontal or inclined tubes lead into vertical headers with the furnace arranged below said tubes and steam and water drums above said tubes.

My invention comprises an improved water circulation which may be used in combination with an improved superheater and feed water heater, and with an improved form of headers and means for fastening the tubes to said headers and for supporting the drum ends. The boiler of my invention can be fired from either end or from both ends.

According to my invention I insert U, V or other shaped deflecting tubes with the back or water inlet ends partially closed in the generating tubes nearest the fires while the other generating tubes more remote from the fires are partially closed at the back or inlet end by inserting discs, preferably made of steel, so formed that they can be driven in at the end of the tubes and held in position by the spring of their respective tubes. In order to allow the water to flow freely into the tubes from the rear headers I cut off a portion, about one quarter to one half, from the lower part of said discs. In this manner I leave the bottom sides of the tubes open to the rear headers and do not form pockets which will collect sediment, while the semi-circular discs at the ends of the upper sides of said tubes stop the circulation of water from doubling back upon itself. I also provide more water and steam space by arranging suitable steam and water drums leading at right angles to the rear end of the boiler from the steam and water drums above the tubes or, if desired, the latter tubes can be suitably connected with a cross drum at the back of the boiler. In this manner I provide considerably more steam and water space and consequently freer circulation without taking up more space.

It is well known that the tubes in this type of boiler when forced form what is generally termed as "steam plugs" and those tubes exposed to the greatest heat often become almost red hot through the water being blown almost entirely out of the said tubes, thereby causing them to bend or hog or sag and start away from the joints in the headers, thus causing grave risk to those attending the fires and great expense in having a continually renew the first few rows of tubes nearest the fires. Now this trouble cannot arise if the heating surface of the boilers can be kept continually covered with water. It is also well known that in boilers where the heating surfaces are kept well covered with water in brisk circulation to carry off the steam bubbles, give a much higher evaporative efficiency than do those boilers in which the tubes become full of steam bubbles or foam when in use instead of water. In my boiler, as above described, U or other shaped tubes are placed inside one or more rows of generating tubes nearest the fires, the lower or rear end of said U tubes being closed. The circulating water enters the generating tubes from the back headers below the U shaped deflecting tubes and discs where it is exposed to the heating surface of said generating tubes and at once boils. The steam, and

boiling water which is lighter than water, rises immediately in said generating tubes and passes into the interior of said U shaped tubes and rushes along the same to the front headers and from thence passes to the steam and water drums thus causing a violent upcast in the front headers and creating a brisk circulation of water over the heating surfaces of all the generating tubes.

It will easily be understood that the steam bubbles or foam formed under the deflecting U tubes in the lower generating tubes is immediately carried through said deflecting tubes by the brisk circulation which is set up in said generating tubes and headers, thereby preventing said lower generating tubes from forming what is known as steam plugs and becoming overheated and at the same time increasing the efficiency of the boiler.

I arrange a form of header adapted to facilitate the cleaning of the external parts of the water tubes and if desired adapted for the reception of superheater tubes. The sides of the headers are corrugated or waved and when said headers are in their places the said corrugations in adjacent headers are opposite to each other which allows of a space between the sides of the headers adapted to allow of the insertion of a tube brush or scrapers for cleaning the external surface of the tubes. In this manner I do away entirely with the necessity of providing cleaning doors in the sides of the boiler and consequently a number of boilers of this type can be placed close up side by side thereby saving considerable floor space.

The spaces between the headers formed by the corrugations may be used for inserting looped or other shaped superheater tubes from the front end of the boiler, the said tubes being carried through the tube chamber and through similar headers arranged at the rear of the boiler and led into special superheater headers arranged at the back of the boiler behind the rear headers, said superheater headers being connected with steam boxes arranged on top of the rear end of the boiler.

The steam generated by the boiler passes into one or other of said steam boxes from which it travels down into one half of the superheater headers and then travels through the superheater tubes which pass through the hot gases in the tube chambers to the smoke box end of the boiler and through the looped tubes around the front headers and back through the tube chamber to the other half of the superheater headers at the rear of the boiler, from whence it passes into the other steam box and is led away to the engine or elsewhere.

It will be seen that by using this arrangement of headers the superheater can be placed in either the hottest or the coolest part of the gases to create any required temperature of steam. Further one or more of said tubes can be withdrawn into the stoke hole and replaced by simply opening the smoke box doors and driving the tubes out of the superheater headers.

As an alternative arrangement of the superheater I may provide horizontal steam boxes behind the headers one above the other and pass the superheater tubes from one steam box through spaces formed by the corrugations of adjacent headers to the front of the boiler and back by forming vertical loops in said tubes to the other steam box through spaces in the same vertical planes formed between said pairs of headers.

Similar headers may be used for an economiser on the top of the boiler in which case the headers are preferably arranged horizontally instead of vertically.

The corrugated or waved shaped header lends itself very well for that type of boiler which is made up into very light segments for transport purposes. For instance instead of having the generating tubes expanded into the headers in the usual way they can be brought through the spaces formed by the corrugations of adjacent headers and connected with the outside of said headers by suitable double bends provided with convenient flanges, unions or other means. It will be easily understood that by this arrangement the corrugated header protects the bends and screwed or other joints formed in the generating tubes form the fire and gases while the whole boiler can be made up into very light

elements and erected by unskilled labour as it will be simply a metter of jointing and bolting the various parts together.

Another feature of my invention is the special method of fixing the tubes in the headers to facilitate the jointing and withdrawal of the same. Instead of expanding the tubes in the ordinary way, I may arrange a stuffing box and gland inside the header. The tubes are arranged in the ordinary way through the headers but instead of expanding the tubes I fill said stuffing box with a soft copper ring or other suitable packing capable of withstanding the heat and I then screw the said gland tight up on the copper ring, thereby making a tight joint around the ends of the tubes.

It will be obvious that this method of connecting the tubes with the headers lends itself for transport purposes as the tubes can be packed separately and jointed up by unskilled labour.

In order to stiffen or stay the drum ends instead of using longitudinal stays or gusset stays of the ordinary type which are found to some extent to prevent access to the boiler tubes, I may use in order to support said ends, heavy crossbars secured by heavy angle iron bars to the drum ends. These supporting crossbars can be fitted on either the inside or the outside of the drum. For use on the outside of the drums the seams can be conveniently rivetted by a hydraulic machine.

It will be obvious that the above type of boiler is equally suitable for marine or land use. In the former case the flue or funnel is carried from the top of the boiler and in the latter case the gases can be led from the drum into the downtake at the back of the boiler.

In order to adapt the above described improvements for large double ended boilers it is only necessary to have two boilers placed back to back in which case the steam and water drums will run the whole length of the two boilers making one complete unit. In another arrangement the one boiler can be made longer and fired from both ends in which case the mud drums can be arranged either above or below the furnace doors.

It must be understood that I do not limit myself to the precise construction and arrangement of the parts above described but I may use the mechanical equivalents of said parts to achieve the same ends without departing outside the scope of my invention.

Dated this 7th day of April, 1908.

W. P. THOMPSON & Co.,
322, High Holborn, London, W.C.,
And at Liverpool and Bradford,
Patent Agents for the Applicant.

COMPLETE SPECIFICATION.

"Improvements in and relating to Water Tube Boilers."

I, John Prothero Davies, of 19, Fawe Park Road, Putney, in the County of London, Engineer, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

My invention relates to that type of water tube boiler in which horizontal

or inclined tubes lead into vertical headers with the furnace arranged below said tubes and steam and water drums above said tubes.

My invention comprises an improved water circulation which may be used in combination with an improved superheater and feed water heater and with an improved form of headers and means for fastening the tubes to said headers and for supporting the drum ends. The boiler of my invention can be fired from either end or from both ends.

It is well known that tubes in this type of boiler when "forced" form what are generally known as "steam plugs" and those tubes exposed to the greatest heat often become red hot through the water being blown almost entirely out of the said tubes, thereby causing them to bend or hog or sag and start away from the joints in the headers thus causing grave risk to those attending to the fires and great expense in having to continually renew the first few rows of tubes nearest the fires. Now this trouble cannot arise if the heating surface of the boilers can be kept continually covered with water. It is also well known that boilers where the heating surfaces are kept well covered with water in brisk circulation to carry off the steam bubbles, give a much higher evaporative efficiency than do those boilers in which the tubes become full of steam bubbles or foam when in use instead of water.

According to my invention I provide means in the generating tubes whereby I am able to take up the boiling water as it rises in said tubes and to pass it freely to the upcast headers thus causing a violent upcast and creating a brisk circulation.

In my boiler U or other shaped troughs are placed inside one or more rows of generating tubes nearest the fires, the lower or rear end of said U troughs being closed by means of discs inserted in the rear ends of the generating tubes. The circulating water enters the generating tubes from the back headers below the U shaped deflecting troughs and discs where it is exposed to the heating surface of said generating tubes and at once boils. The boiling water which is lighter than the entering water, rises immediately in said generating tubes and passes into the interior of said U shaped troughs and rushes along the same to the front headers and from thence passes to the steam and water drums, thus causing a violent upcast in the front headers and creating a brisk circulation of water over the surfaces of all the generating tubes. It will be easily understood that the boiling water under the deflecting U troughs in the lower generating tubes is immediately carried through said deflecting troughs by the brisk circulation which is set up in said generating tubes and headers, thereby preventing said lower generating tubes forming what is known as steam plugs and becoming overheated and at the same time increasing the efficiency of the boiler.

My invention is more particularly described with reference to the accompanying drawings, in which:—

Figure 1 shows a front elevation of a water tube boiler.

Figure 2 shows a sectional elevation on the line A B of Figure 1.

Figure 3 shows a detail view of the method of arranging the superheater.

Figure 4 shows a sectional elevation of a water tube boiler with an alternative arrangement of the superheater tubes.

Figure 5 shows a front elevation of the boiler shown in Figure 4.

Figure 6 shows a front sectional elevation on the line C—D of Figure 4.

Figure 7 shows a sectional elevation of a double ended type of water tube boiler.

Figure 8 shows a sectional elevation of a land type of water tube boiler.

Figures 9, 10 and 11 show detail views of the method of securing the internal U shaped circulating troughs and discs in the generating tubes.

Figures 12 and 13 show detail views of an alternative method of securing the discs to the generating tubes.

Figure 14 shows a detail view of the method of securing the generating tubes to the headers.

Figures 15 and 16 show detail views of supporting the drum ends.

Referring now to the drawings, I insert U, V, or other shaped deflecting troughs 1 in the generating tubes 2 nearest the fires, said generating tubes with the other generating tubes more remote from the fires being partially closed at their back or inlet ends by means of the discs 3, as shown more particularly in Figures 11 and 12.

In order to allow the water to flow freely into the tubes from the rear headers 4 I cut off a portion about one quarter to one half from the lower part of said discs 3. In this manner I leave the bottom sides of the tubes open to the rear headers and do not form pockets which will collect sediment while the semi circular discs at the ends of the upper sides of said generating tubes stop the circulating water from doubling back upon itself. The said deflecting tubes 1 are supported in their generating tubes by means of stays 5 arranged at suitable intervals. I prefer to use the method shown in Figures 10 and 11 of securing the discs 3 to the back or water inlet ends of the generating tubes 2. I provide on the inner sides of said discs a pair of projecting wings 6 adapted to engage with the internal surface of the generating tubes 2. I also provide in said discs stud holes 7 provided with a projecting tapering surfaces 8. At the ends of the studs 9 I provide blocks 10 rounded on their upper sides to correspond with the internal surfaces of the generating tubes and provided with a tapering surface 11 on their lower sides corresponding with the said tapering surface 8, projecting from the inner side of the said disc 3.

It will be readily understood that by tightening the nut 12 the said disc 3 can be securely fastened to the generating tube.

In Figures 12 and 13 I show an alternative method of fastening said disc 3 to the generating tube. I provide a spring 13 which is first driven into the end of the generating tube and behind said spring I arrange a bar 14 provided with a stud hole adapted to correspond with a stud hole in the said disc 3. It will be readily understood from Figure 13 that when the stud 15 is tightened by means of its nut 16, the disc 3 can be firmly secured to the spring 13 and thus to the generating tube into which said spring has been driven.

In Figures 1, 2 and 4 of the drawings I show an arrangement of steam and water drums of that class in which a steam and water drum mounted in the front of the boiler is connected with the front headers and with cross drums connected either with the back headers, as shown in Figure 2, or with a rear drum parallel with said front drum, as shown in Figure 4. In the boiler of my invention I provide in the drums considerably more steam and water space than has been previously suggested and consequently I obtain a freer circulation through said drums from the front headers to the back headers without taking up more ground space.

I provide a cross drum 18 adapted to receive the upper ends of the front headers 19 and leading at right angles to the rear end of the boiler I provide three longitudinal drums 20 adapted to receive the upper ends of the back headers 4, as shown in Figure 2, or connected with a rear drum 41 parallel with said front drum 18, as shown in Figure 4.

As shown more particularly in Figures 1, 6 & 9, I use in the boiler of my invention a form of header of the class provided with corrugated and waved sides which have been suggested hitherto for the purpose of facilitating the cleaning of the external parts of the water tubes.

The spaces formed by the corrugated sides of the headers can be used, as shown in Figure 1, for inserting looped or other shaped superheater tubes 21 from the front end of the boiler, said superheater tubes being carried through the tube chamber and between the back headers into the special superheater headers 22 (see Figures 2 and 3), arranged at the back of the boiler behind the rear headers 4. The said superheater headers are connected by means of

tubes 23 with the steam boxes 24. The steam generated by the boiler passes from the drums through the outlet 25, shown broken away, into one or other of the said steam boxes 24 from which it passes down through the tubes 23 to one of each pair of the superheater headers 22 and then travels through the superheater tubes 21 which pass through the hot gases in the tube chamber to the front or smoke box end of the boiler and around the front headers back through the tube chamber to the other half of the superheater headers at the rear of the boiler from whence it passes into the other steam box and is led away through the outlet 26 to the engine or elsewhere.

It will be seen that by using this arrangement of headers the superheater can be placed in either the hottest or coolest part of the gases to create any required temperature of steam. Further one or more of said tubes can be withdrawn into the stoke hole and replaced by simply opening the smoke box doors and driving the tubes out of the superheater headers.

In Figures 4 and 6 I show an alternative arrangement of the superheater above described. I provide a pair of horizontal steam boxes 24 and I pass the superheater tubes 21 from one steam box through the spaces formed by the corrugations of adjacent headers to the front of the boiler and back to the other steam box by forming vertical loops in said tubes.

As shown in Figure 1 an economiser 27 may be provided on the top of the boiler in which case the headers are preferably arranged horizontally instead of vertically. The feed water enters the economiser through the inlet 28 and passes to the drums and steam generating tubes through the feed outlet 29, the said feed outlet being preferably formed by a rising pipe, as shown, in order to prevent the economiser from being emptied by gravity.

It will be seen that this arrangement allows the feed water to enter at the top and gradually get heated up as it travels down to meet the hotter gases of combustion.

It will be easily understood that the corrugated or waved shaped header lends itself very well to that type of boiler which is made up by very light segments for transport purposes. For instance instead of having generating tubes extended into the headers in the usual way they can be brought through the spaces formed by the corrugations of adjacent headers, and connected with the outside of said headers by suitable double bends provided with convenient flanges or unions or other means. It will be easily understood that by this arrangement the corrugated header protects the bends and screwed or other joints formed in the generating tubes from the fire and gases while the whole boiler can be made up into very light elements and erected by unskilled labour as it will be simply a matter of jointing and bolting the various parts together.

Instead of expanding the tubes in the ordinary way I prefer to use a special method of fixing the tubes in the headers of the class in which a gland and packing is used in order to facilitate the jointing and withdrawal of the same.

As shown in Figure 14 I may arrange on the internal surface of the headers a stuffing box 30 and a gland 31. The tubes are passed through the headers in the ordinary way but instead of being expanded the stuffing box 30 is filled with a copper ring 32 or other suitable packing capable of withstanding the heat, and the gland is then screwed tight upon said packing ring, thereby compressing it and causing it to make a tight joint around the ends of the said generating tubes 2. It will be obvious that this method of connecting the tubes with the headers lends itself for transport purposes as tubes can be packed separately and joined up by unskilled labour.

I may support the drum ends as shown in Figures 15 and 16 by means of heavy cross bars 33 secured by heavy angle iron bars 34 which must be carried right across the drum ends and round the flanges of said ends and rivetted to the shells of the drums. It is found that the flanging of the ends by hydraulic presses tends to cause a weakness or fracture at the bend and consequently I am able by my arrangement of cross bars 33 to support the weakest part of

said ends. It will be obvious that instead of fitting these supporting cross bars on the inside of the drum, if said drum ends are inverted, said cross bars can be fitted on the outside of the drum. If used on the outside of the drum the seams can be conveniently rivetted by a hydraulic machine.

The above described boiler is equally suitable for marine and land use. In Figures 1 and 2 I illustrate the boiler of my invention arranged as a marine boiler, in which case the flue or funnel is carried from the top of the boiler through the outlet 35.

In Figures 4, 5 & 6 and in Figure 8 I show a form of my boiler suitable for land use. The gases of combustion pass from the furnace through the tubes around the baffles 38 into a downtake 39 arranged at the back of the boiler. It will be seen that in this boiler the back headers 4 are entirely protected from the gases of combustion as they rise from the furnace by means of the dividing wall 40.

In Figure 7 I show a double ended form of my boiler with two furnaces arranged across the tubes. It will be seen that the gases of combustion pass from both furnaces through the tubes around the baffles 36 out through a flue 37 arranged at the top of the boiler.

Finally it should be mentioned than many years ago troughs were some times introduced into the water tubes of steam generators but such troughs have hereto always had open ends and have sometimes been divided into compartments. These troughs were used either for the purpose of obtaining a return circulation through the generating tubes in which they were used or for the purpose of catching the sediment and were not arranged or adapted to take up the boiling water as it rises in said tubes and to pass it freely to the upcast headers in order to create a brisk circulation.

An arrangement was also suggested in which the back ends of the generating tubes were connected with the back headers by means of tubes of less diameter than said generating tubes in order to allow of the use of a series of back headers corresponding in number with said generating tubes.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. In a water tube boiler, the provision of means in the generating tubes for taking up the boiling water as it rises in said tubes and conveying it freely to the upcast headers, substantially as and for the purpose described.

2. In a water tube boiler, the provision of deflecting circulation troughs in the generating tubes nearest the fires, said circulation troughs being closed at their back or inlet ends, substantially as and for the purpose described.

3. In a water tube boiler of the character claimed in Claim 2, the provision of generating tubes with the upper part of their back or inlet ends closed, substantially as and for the purpose described.

4. In a water tube boiler of the character claimed in Claims 2 and 3, the provision of semi-circular discs adapted to close the upper part of the back or inlet ends of the generating tubes, said discs being bolted to said tubes, substantially as and for the purpose described.

5. In a water tube boiler of the character claimed in Claim 4, the provision of projecting wings on the inner surface of the closing discs and tapering surfaces adapted to be tightened by a bolt to compress said projecting wings against the internal surface of the generating tube, substantially as described with reference to Figures 9, 10 and 11 of the accompanying drawings.

6. In a water tube boiler of the character claimed in Claim 4, the provision of a spring adapted to be driven into the end of the generating tube, and a holding plate adapted to be arranged behind said spring and bolted to the semi-circular closing disc substantially as described with reference to Figures 12 and 13 of the accompanying drawings.

7. In a water tube boiler of the character described, the arrangement of a steam and water drum mounted in the front of the boiler connected with the upper ends of the front headers and a series of cross drums leading at right angles to said front drum to the rear of the boiler, and connected either with the back headers or with a rear drum parallel with said front drum, said drums being adapted to allow a free circulation to pass from the front headers to the back headers, substantially as described.

8. In a water tube boiler of the character described, the arrangement of a series of superheater tubes looped around or between the front ends of the headers, said superheater tubes being carried through the tube chamber into special superheater headers connected with steam drums or boxes or directly into said steam drums or boxes, substantially as and for the purpose described.

9. In a water tube boiler provided with a series of headers with corrugated or waved sides and spaces formed between said headers, the arrangement of generating tubes brought through the spaces formed between the headers and connected with the outside of said headers, substantially as and for the purpose described.

10. In a water tube boiler of the character described, the provision of means for jointing the generating tubes to the headers, comprising a stuffing box on the inner surface of each header, a packing ring in said stuffing box and a gland, said stuffing box being adapted to receive the end of a generating tube and said gland being adapted to compress said packing ring around said generating tube, substantially as described with reference to Figure 14 of the accompanying drawings.

11. In a water tube boiler the provision of means for supporting the ends of the steam and water drums comprising cross bars secured by angle iron bars to the drum ends, substantially as described with reference to Figures 15 and 16 of the accompanying drawings.

12. In a marine water tube boiler the construction and arrangement of parts, substantially as described with reference to Figures 1, 2 and 3 of the accompanying drawings.

13. In a water tube boiler the construction and arrangement of parts substantially as described with reference to Figures 4, 5 and 6, or with reference to Figure 8 of the accompanying drawings.

14. In a double ended water tube boiler the construction and arrangement of parts, substantially as described with reference to Figure 7 of the accompanying drawings.

Dated this 7th day of October, 1908.

W. P. THOMPSON & Co.,
322, High Holborn, London, W.C.,
And at Liverpool, and Bradford,
Patent Agents for the Applicant.

Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.
[Wt. 57—50/9/1910.]

Fig:1

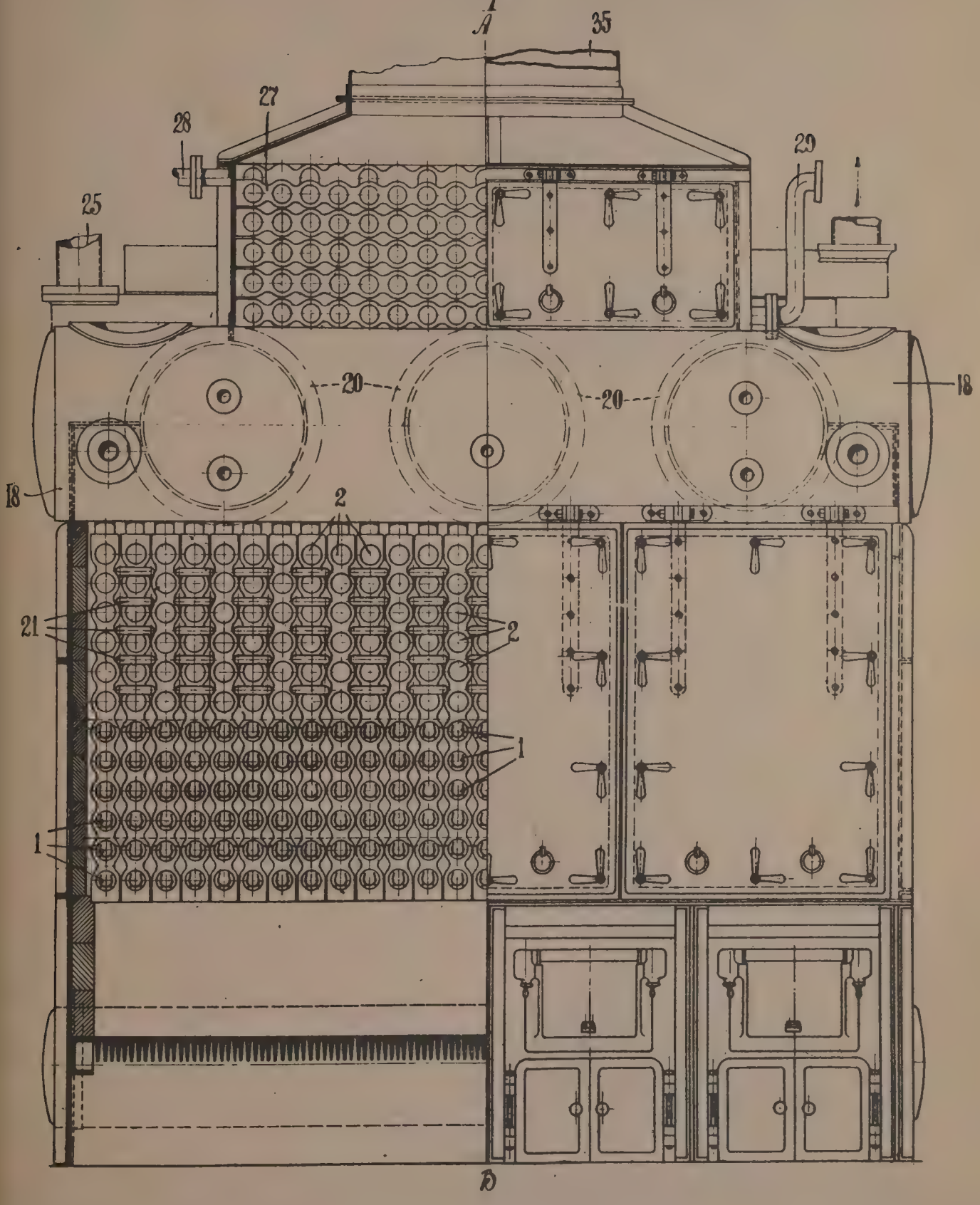


Fig. 2

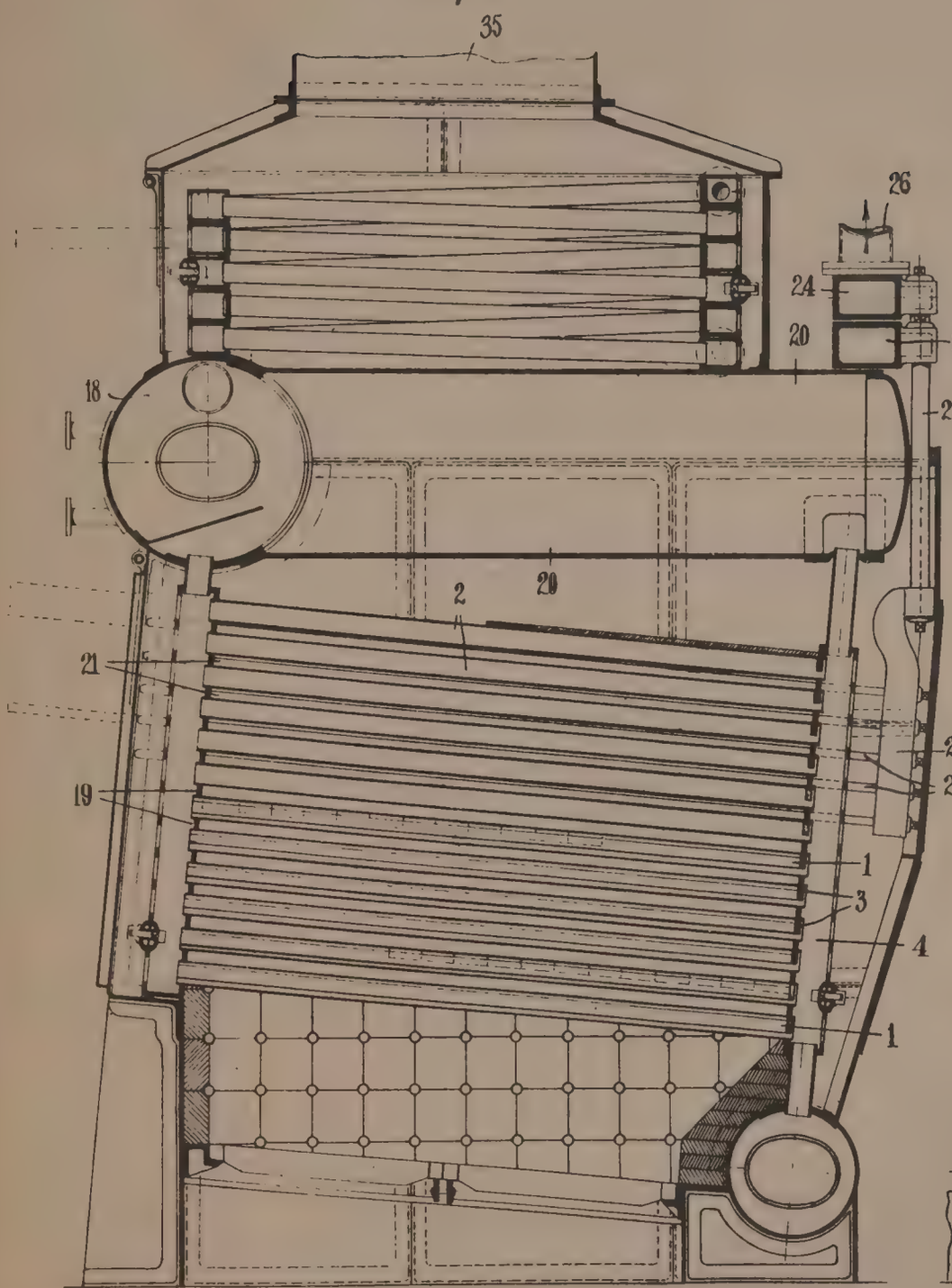
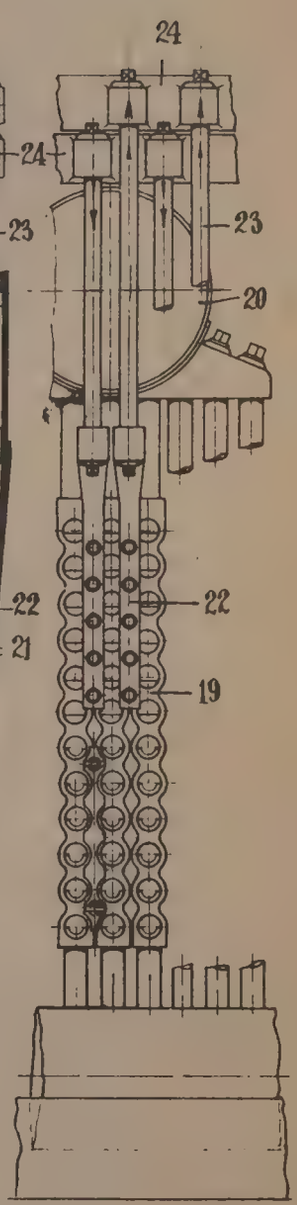


Fig. 3.



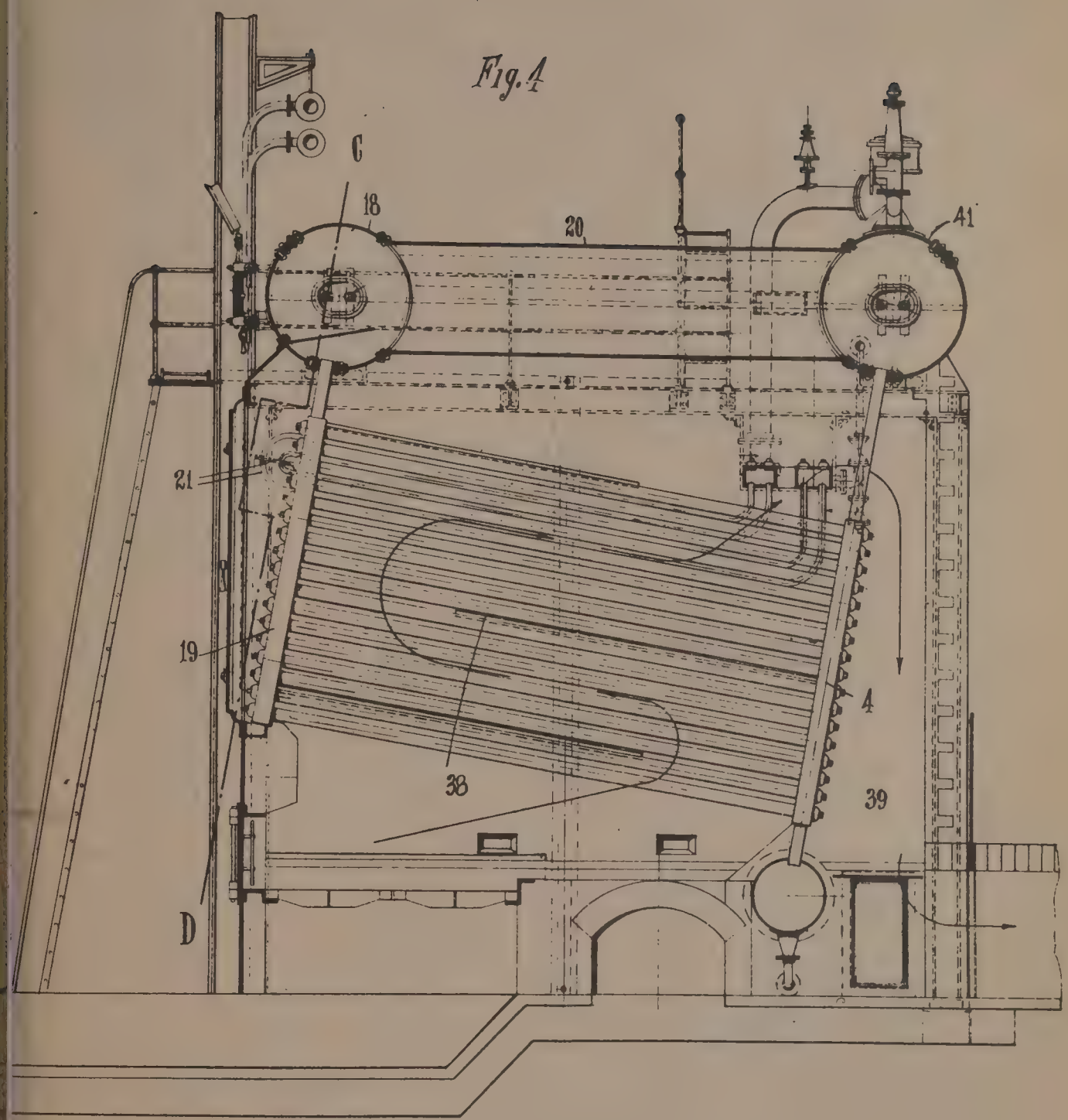


Fig. 4
C
18
20
41
21
19
4
38
39
D

Fig. 5

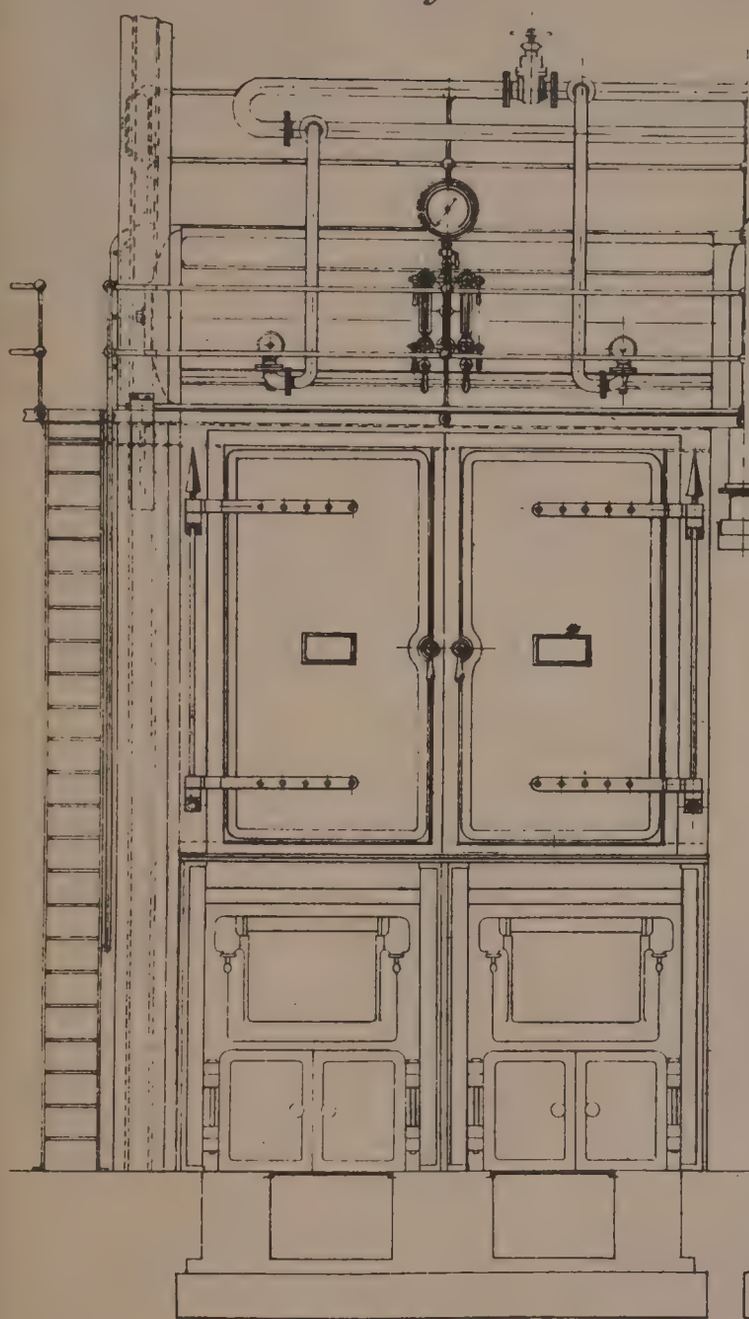


Fig. 6

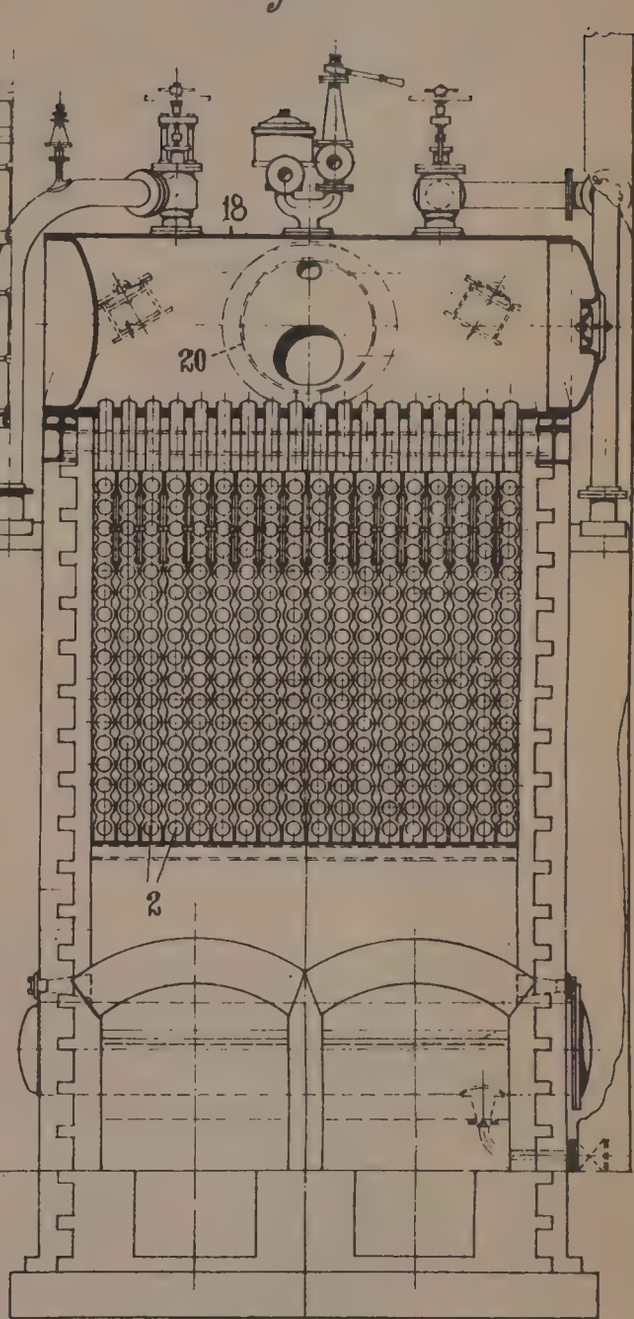


Fig. 7.

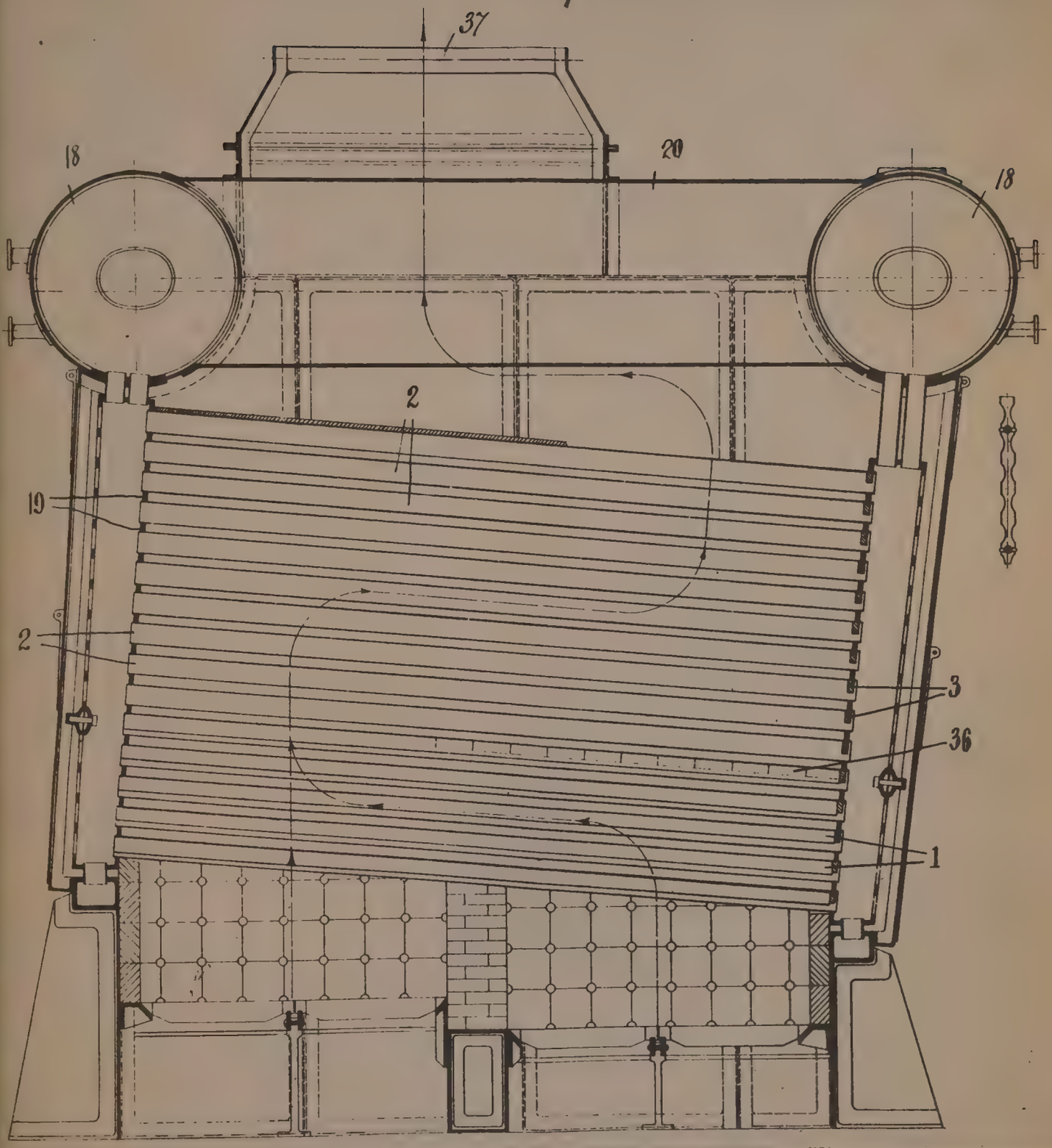


Fig. 8.

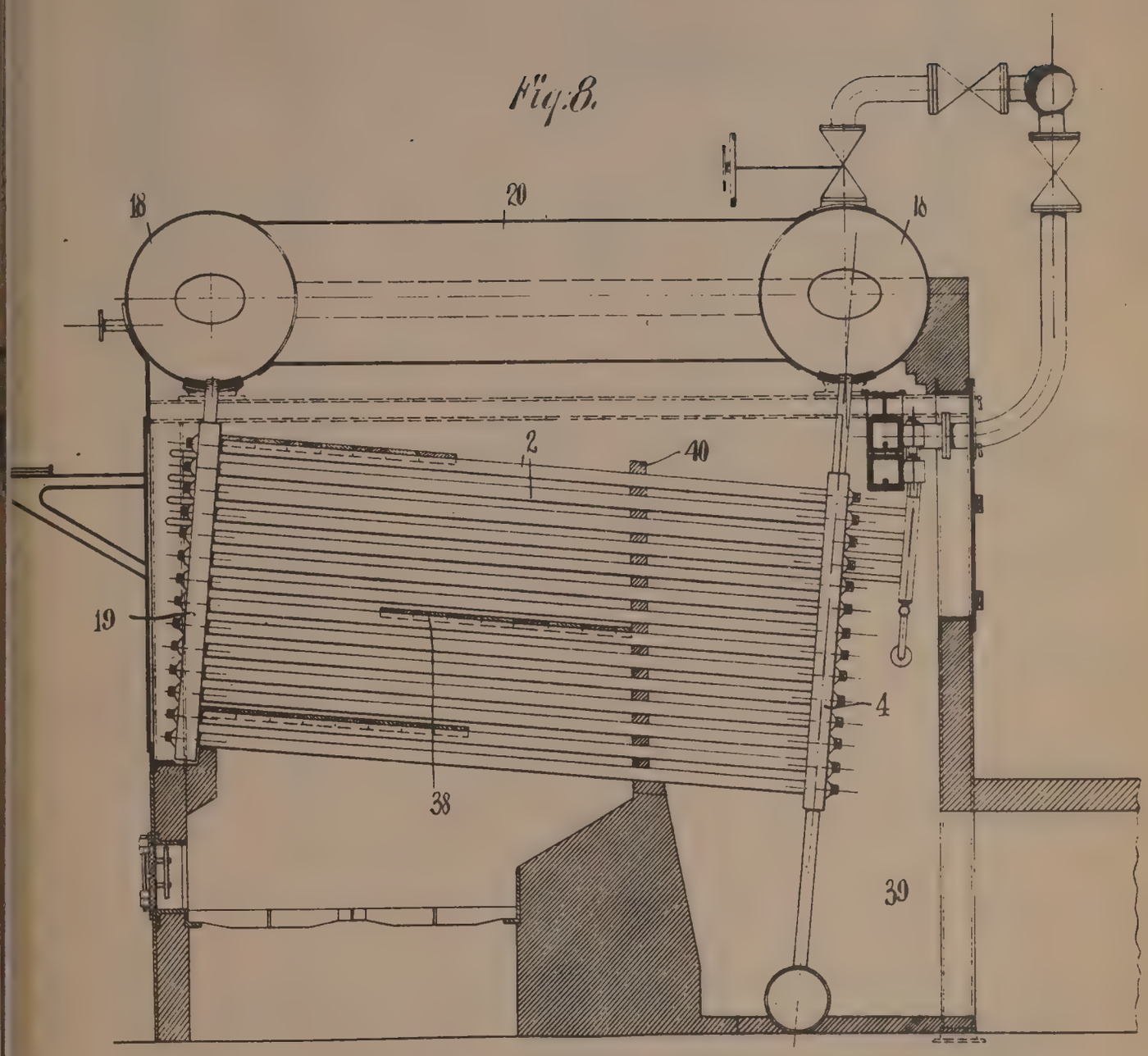


Fig.9

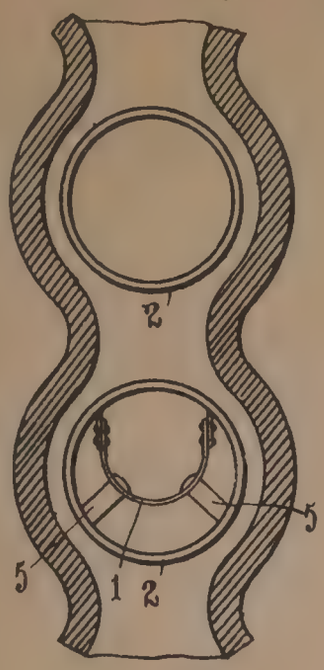


Fig.10

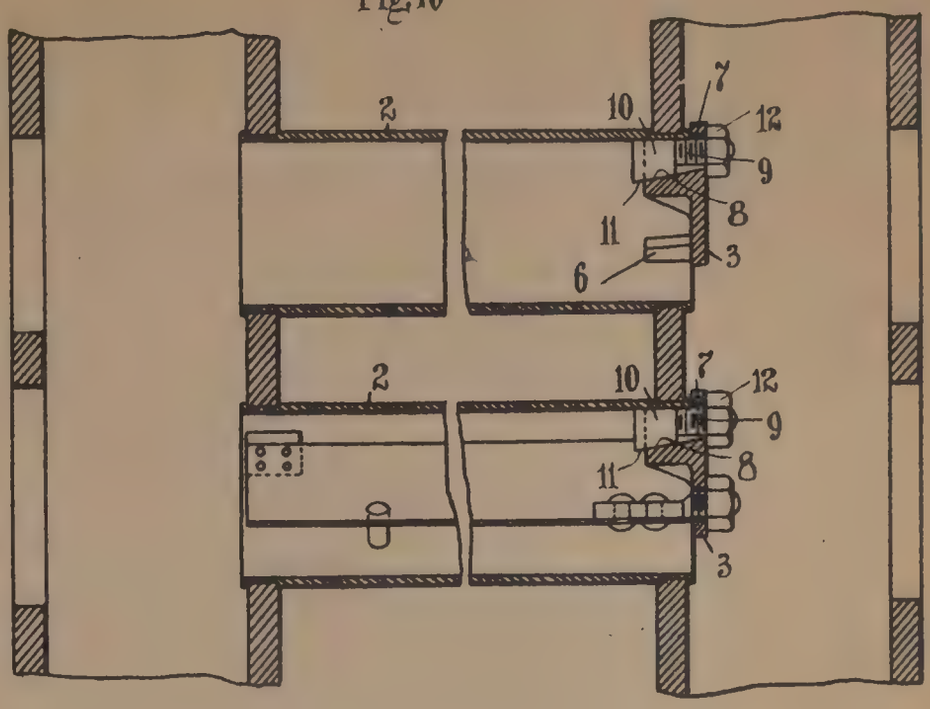
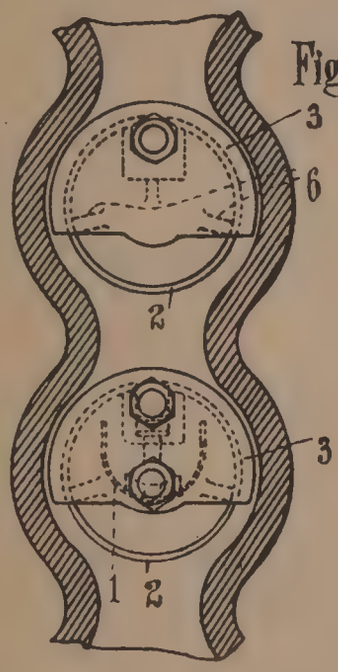


Fig.11



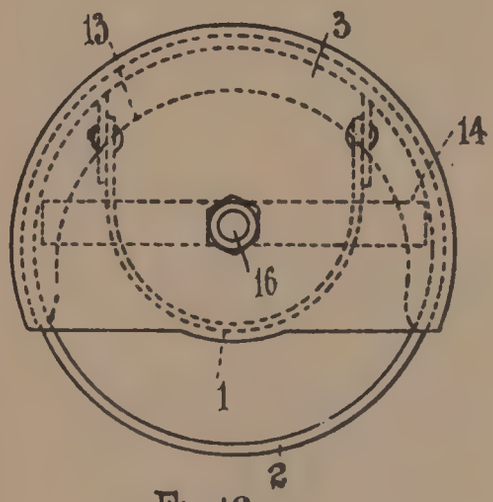


Fig.12

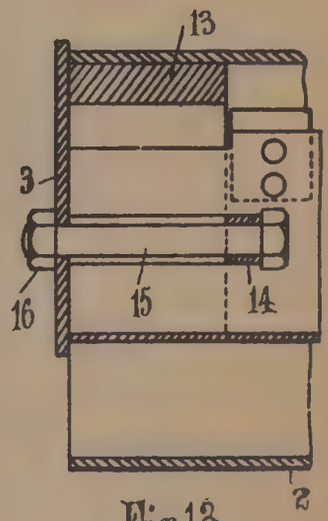


Fig.13

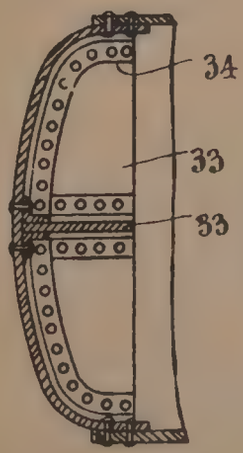


Fig.15

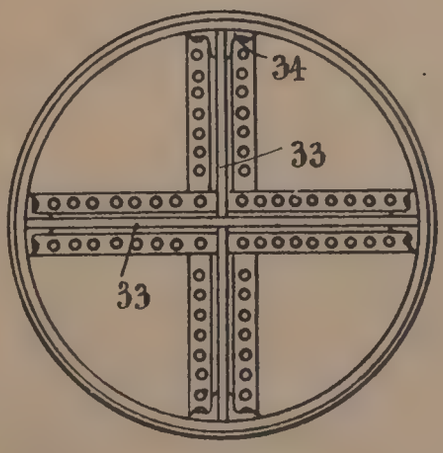


Fig.16

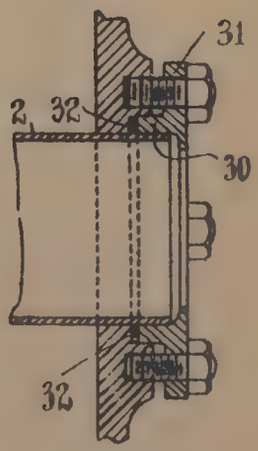


Fig.14

DEFENDANT'S EXHIBIT K. 1411

A. D. 1873, 4th February. No. 412.

Tubular Boilers.

LETTERS PATENT to Henry Simon, of Manchester, in the County of Lancaster, Civil Engineer, for the Invention of "IMPROVEMENTS IN TUBULAR BOILERS AND HEATING TUBES."—A communication from abroad by Fredrich Ludwig August Buttner, Civil Engineer, of Aachen.

Sealed the 13th May 1873, and dated the 4th February 1873.

SPECIFICATION in pursuance of the conditions of the Letters Patent filed by the said Henry Simon in the Great Seal Patent Office on the 1st August 1873. 1412

To all to whom these presents shall come, I, Henry Simon, of Manchester, in the County of Lancaster, Civil Engineer, send greeting.

Whereas Her most Excellent Majesty Queen Victoria, by Her Letters Patent, bearing date the Fourth day of February, in the year of our Lord One thousand eight hundred and seventy-three, in the thirty-sixth year of Her reign, did, for Herself, Her heirs and successors, give and grant unto me, the said Henry Simon, Her special licence that I, the said Henry Simon, my executors, administrators, and assigns, or such others as I, the said Henry Simon, my executors, administrators, and assigns, should at any time agree with, and no others, from time to time and at all times thereafter during the term therein expressed, should and lawfully might make, use, exercise, and vend, within the United Kingdom of Great Britain and Ireland, the Channel Islands, and Isle of Man, an Invention for "Improvements in Tubular Boilers and Heating Tubes," a communication to me from abroad by Frederich Ludwig August Buttner, Civil Engineer, of 1413

1414 Aachen, upon the condition (amongst others) that I, the said Henry Simon, my executors or administrators, by an instrument in writing under my, or their, or one of their hands and seals, should particularly describe and ascertain the nature of the said Invention, and in what manner the same was to be performed, and cause the same to be filed in the Great Seal Patent Office within six calendar months next and immediately after the date of the said Letters Patent.

Now Know Ye, that I, the said Henry Simon, do hereby declare the nature of my said Invention, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

1415 These boilers belong to the class of tubular boilers in which the water passes through the tubes.

There are two classes of such boilers, namely.,—

1st. Boilers in which the circulation of water is not forced along a certain way, but only induced by the heat, and in which circulation is favoured by some special arrangements, such as inner tubes or diaphragms (to this class belong Field's, Alban's, and Howard's boilers).

2nd. Such others in which the circulation of water is forced through all the pipes (to this class belong Belleville's boiler and Root's safety boiler). My construction belongs to

1416 this second class of boilers.

In these boilers each molecule of water is obliged to run a great distance in zig-zag all along the heating surface from the inlet to the outlet of the boiler, whilst in the boilers of the first class, mentioned above, the molecule can pass shortly and nearly straight through the boiler. These boilers of the first class have therefore the defect of supplying wet steam and priming. On the other hand all the known boilers belonging to the second class have the defect that each tube is connected with the others both at the inlet and

outlet, by which arrangement the tubes cannot expand freely, and this necessitates frequent repairs. 1417

Now the principle of my construction is to fix the tubes on one side only, to have them communicating on that side only, and to promote the circulation of the water through each tube, either by small interior tubes (Figs. 1–14), or by inserting inside sheet iron strips or diaphragms (Figs. 15–20 and 27–29), and to divide the communication chamber by partitions in such a way as to oblige the water to pass through zig-zags established in the boiler. The difference between Field's tubes and my arrangement is clear, for the former cannot be used in a horizontal position, and mine not in a vertical position. 1418

The first point I will refer to is the tubular feed water heater. By the use of wrought-iron walls it is not possible to utilise the heat contained in the fire-gases over a certain degree, for as soon as they are cooled down to this degree the wrought iron becomes deteriorated. Therefore, in order to obtain the greatest possible advantages out of the gases the extremity of the boiler must be of cast iron, and for security's sake of cast-iron tubes.

In order to obtain a great difference of temperature the cold water is introduced here, and forms in this way a feed water heater, and the otherwise lost heat of the fire-gases is thus utilised. 1419

The principles of my constructions are—

(1). The tubes are horizontal or very nearly horizontal.

(2). Great facilities are provided for reaching the extremities of the tubes, so that they can be cleaned of the soot outside, and by taking away the end cap for cleaning the tubes from deposits inside.

If the water is very soft the tubes communicate only on

1420 one side, so that in this case there exists no forced circulation.

If the water is hard the tubes communicate at both ends, and the circulation of water engendered washes the deposits into a pipe provided at one end below the others, out of which they are very easily driven by blowing off occasionally.

The general arrangements are for the purpose of utilising entirely the fire-gases without the use of a ventilator, for which purpose it is necessary that (1) the gases reach progressively colder surfaces, namely, in the first instance, the boiler, afterwards a feed water heater under pressure, then
1421 an air heater, and at last an open water heater; (2) that there are as few obstacles as possible to the draught. The draught is vertical, and has only a short way to the chimney on account of the greatly divided heating surfaces.

The following are the details which I consider may be advantageously adopted for carrying out this Invention.

Description of Drawings.

Fig. 1 and 2 show the details; Fig. 3 and 4 show the general disposition of a boiler.

All the tubes *a, a,* are to be fixed in the tube wall *b* and
1422 closed at the other end where they are supported by a cast-iron railing *c*, and fixed by a peg *n*. Behind and parallel to the railing is a sheet-iron door c^1 by which access can be had to the tubes, and the soot can be easily cleaned out.

The chamber of communication (at the front) is formed by the tube wall *b* and an outer wall *d*. Between the same are adjusted, on three of the sides, bars *e, e, e;* on the fourth or upper side and above is the neck piece s^1 of the steam collector *s*. Partitions *f, f,* divide the chamber in such a way as to separate one tube entirely from the others. In each

tube is an interior tube *g* (with the exception of the lower 1423
row of tubes which are supplied with the feed water at the farther end) communicating with the partition next below it in the chamber of communication. The ends of the tubes *g* do not reach up to the closed extremity of the tubes *a*. In front of each tube *a*, and in the outer wall *d*, a screw plug is inserted. The interior tubes *g* are maintained in their position by a plug *h* (fixed in the screw plug), and also by the pieces *k*, *k*, which support their ends. The plates *b* and *d* are joined by stays.

The water supply is delivered at the farther end into the under row of tubes, and once at the front it runs into the
inside tubes of the second range of tubes back through their 1424
annular space, up in the inner tubes of the third range, and so on. Running in this way through all the tubes, as water, as foam, as wet steam, and as dry or superheated steam it arrives at the upper part through the holes of the necks s^1 into the steam collector *s*, from which it goes into the steam engine. The firebars are underneath the lowest range of tubes.

Fig. 5, 10, show the communication chambers formed of cast iron. According to Fig. 5, 6, they contain each one vertical range of tubes only, and according to Fig. 7, 10, they
contain two ranges each; Fig. 9, 10, show the connections 1425
forming a boiler; Fig. 5, 6, show the screw plug replaced by closing plates held in their places by bolts; Fig. 11, 14, shows a similar boiler, in which the tubes are fixed thus $^{0}_{0}{}^{0}$ instead of as in the former thus 8 $_{0}$. In consequence of which the partitions of the communication chambers become simpler, viz., straight. The tube ranges are horizontal, and the separate tubes do not require to be separated one from the other.

In order that the water should have a quicker circulation in the under tubes it is supplied only in some of them from

1426 behind. These tubes must be so separated at the front that they are connected only with the inside tubes of their neighbouring tubes. They will be also laid a little deeper in order to allow the steam an easy escape (see Fig. 11, 12).

Fig. 13, 14, show how the chamber of communication can be constructed in several pieces vertically; Fig. 13, 18, show a boiler in which the tubes are separated in two by long sheet iron strips *p, p,* which do not reach entirely the closed end of the tubes, and which serve instead of the inner tubes. The chamber of communication is also divided by iron partitions *q, q,* which are adjusted at each tube range upon the ends of the sheet-iron strips, extending along beyond the
1427 tubes in such a way as to afford capacity for taking out a whole range of iron strips by a single iron band *q*.

The iron strips can be stiffened by small ribs fixed thereon. Thus the water is obliged to advance through the under half, and to flow back through the upper half of the tubes, and to pass in this way all the tubes from the under to the upper parts. The tubes into which the water is supplied behind are out of the range of the lowest band *q*, so that the water may flow from these first tubes to the lower half of the next row or range. In this case, as well as in the above-described construction, there are no single closing plates in
1428 front of each tube, but a plate *d* replaces them, which can be taken away completely.

Fig. 19, 20, show how the same construction can be used for ships' boilers. Brick walls are replaced by ranges of tubes entirely close. And in order to render this possible each second tube of such a range is fixed in a communication tube *v* behind the boiler (opposite the communication chamber). Marked on the front is also such a communication tube turning round the fire-place and the ash-pit, and discharging on both sides into the communication chamber.

Before each of the communication tubes a plug or plate is 1429
provided, and each of these tubes is divided by strips p, as described before. The water is supplied to those tubes below which are situated in the middle. The tube walls are again surrounded by a sheet-iron covering.

Fig. 21, 23, show there is also a feed water heater for water which leaves much deposit. The said heater is composed of horizontal tube ranges a_1, a_1, a_2, a_2, a_3, a_3, a_4, a_4. Each of these tubes are fixed at one end to the collecting pipes b_1, b_2, whilst it communicates by a bend k_1, k_2, with a tube of the following range:—The tubes b_2 and b_3 are cast together in such a way that their chambers communicate 1430
through channels. The water is driven at g into the upper tube b by the feed pump, and runs through the various tubes a_1, a_1, the bends k_1, k_1, and the tubes a_2, a_2, and the chambers o, o, the tubes a_3, a_3, a_3, the bends k_2, k_2, the tubes a_4, a_4, and is lead off by the tube b_4 at h. Running such a long way with a small fall it carries off the deposit out of the openings p, p, and washes the same into the scum pipe c. The deposit can be let out of this pipe by a cock. To render this still more certain a scum bag s is joined to c, and a circulation through c being established all the deposits are carried into this scum bag. The circulation is occasioned by the tube arrangement e_1, e_2, e_3, communicating on both sides with d and c. 1431
The ascending piece is proportionally short compared to e, e, besides it is enveloped so as to be protected against cooling. The cooling of the water in the parts e, e, engenders the desired circulation through c. To approach the back extremities of the tubes it is needed only to open the sheet-iron door m. In this way the tubes can be cleaned of the soot, and by taking away the bends k_1, and k_2, one is enabled to clean away the boiler deposits.

Fig. 24, 26, show a feed water heater for passably clean

1432 water. Tubes a_1, a_2, a_3, communicate only on one end through the transverse tubes b_1, b_2, b_3, to which they are joined by flanges. On the other end they are shut by a simple plate or disc so as to allow cleaning. The tubes b_1, b_2, b_3, are joined together by vertical tubular joint pieces q_1, q_1, q_2, q_2. The water enters above through g and has its outlet at h. The greater specific gravity of the colder water will engender a circulation through the tubes in the direction indicated by arrows. With the lower pipe b a scum collector is connected. In the tubes a, a, no forced circulation exists.

Fig. 27, 29, show another form of construction which produces the same effect as that form shown in Fig. 21, 23. The
1433 vertical tubes lying one above the other are however here all cast together in the same piece, which contains at the same time the passages k_1, k_2, and o. The ends of each tube are provided with covers. In this manner the joints are not subjected to the influence of the inflammable gases, and the unequal expansion of the tubes.

Fig. 30, 32, show the whole arrangement of one of my generators. A is the boiler. Immediately over the same is the high-pressure feed water heater B, the pipes of which are parallel to those of A. Over this lies the air heater C, formed of large cast-iron pipes open at both ends, and laid
1434 in cast-iron plates l, l. Tight joints prevent the cold air from entering into the draught. These pipes receive the cold air at one end, whilst at the other end they open into a channel F connected with a closed ash-pit. The cold air passing through these pipes is warmed, and is conducted under the fire-bars by a channel F. The fire-gases after having passed round the air heater C go along the cast-iron bottom of the open water heater D, and then they enter the chimney E. This cast-iron bottom has a certain number of vertical ribs

in the direction of the draught, in order to utilise the heat of 1435
the escaping fire-gases as much as possible.

Having thus particularly described and ascertained the nature of the said Invention, and in what manner the same is to be performed or carried out in practice, I hereby declare that I claim the Invention of "improvements in tubular boilers and heating tubes, as herein-before described and illustrated by the Drawings accompanying these Presents, it being understood that the following are particular points in this Invention,—

1. In the construction of the boiler the means whereby the zig-zag circulation of the water and steam is engendered 1436
in a boiler consisting of tubes closed at one end, and communicating only on the other end. These means consist of a division of the tubes (with the exception of the part at the back) either by concentric inside pipes or by sheet-iron strips inserted into the tubes, which division is combined with such an arrangement of the chamber of communication that the water and afterwards the steam are forced to a zig-zag circulation through all the tubes; but I consider as unessential the details which are not mentioned herein, as for instance, the degree of inclination of the tubes, the special construction of the water inlet or the steam outlet, the
division of the communication chambers, vertically as in Fig. 1437
9, 10, or horizontally as in Fig. 13, 14.

2. In the construction of the feed water heater (using the ordinary waste fire-gases), the use of cast-iron heating pipes in horizontal ranges in such a way that the same are either joined only on one side, but closed on the other; or joined also on the other end by bends or elbow pieces, so as to oblige the water entering the tubes to run through the tubes in zig-zags from above to below.

3. In both cases the extremities of the tube are easily

1438

reached. The number of ranges is immaterial. The scum collector C, shown in Fig. 22, joined to the tubes *e* and the bag D for the above-mentioned purpose. For such collection also the tube b_4 can be used, if the bag D and the tubes *e* are brought in connection with the outlet pipe.

4. The general arrangement of the generator.

5. The vertical succession of several sets of horizontal ranges of apparatus (viz., of the boiler of the high-pressure feed water heater and of the air heater) with the open feed water heater as a top cover of the whole.

6. Any one of the heating apparatus can be omitted.

1439

7. Or can be modified without changing essentially the general arrangements.

In witness whereof, I, the said Henry Simon, have hereunto set my hand and seal, this 28th day of July, in the year of our Lord One thousand eight hundred and seventy-three.

HENRY SIMON. (L.S.)

Witness,

Emil Adolff,

7, St. Peter's Square, Manchester.

1440

A.D. 1873. Feb. 4. No. 412
SIKORM'S SPECIFICATION

Longitudinal Section

FIG. 1.

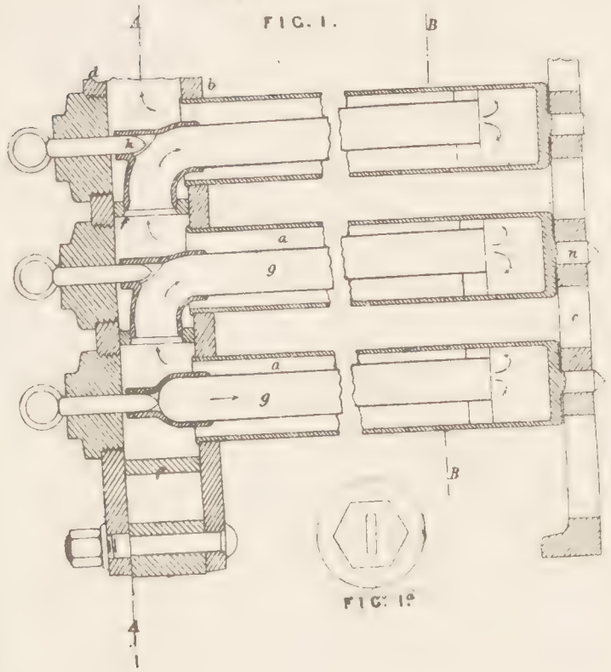
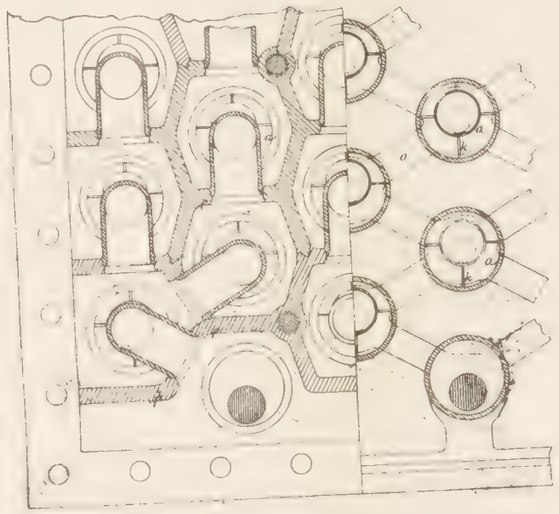


FIG. 1a

Transverse Section at A.A.

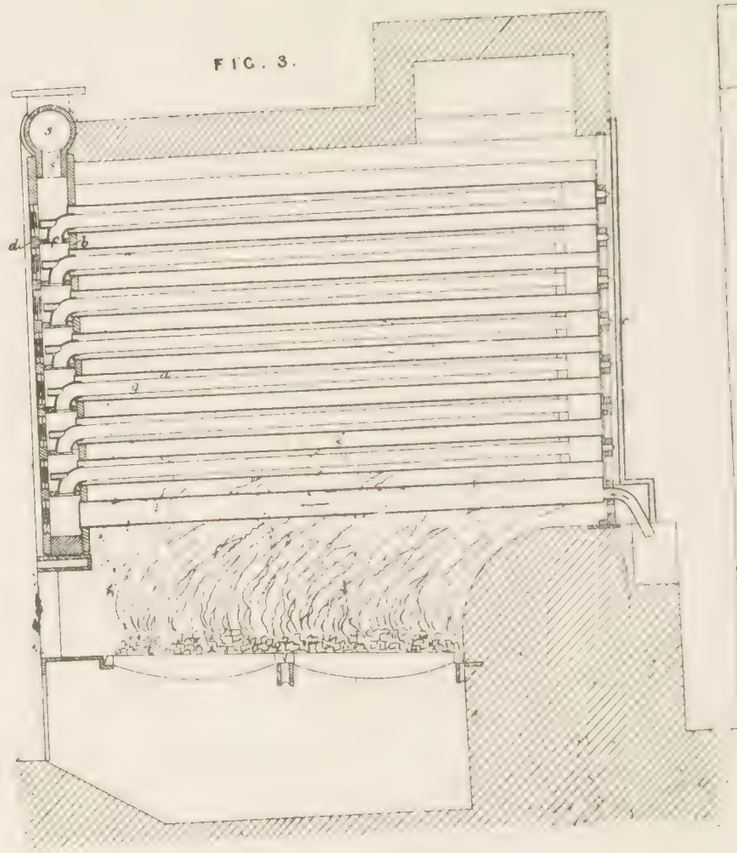
Transverse Section at B.B.

FIG. 2.



Longitudinal Section.

FIG. 3.



Sectional Front View.

FIG. 4.

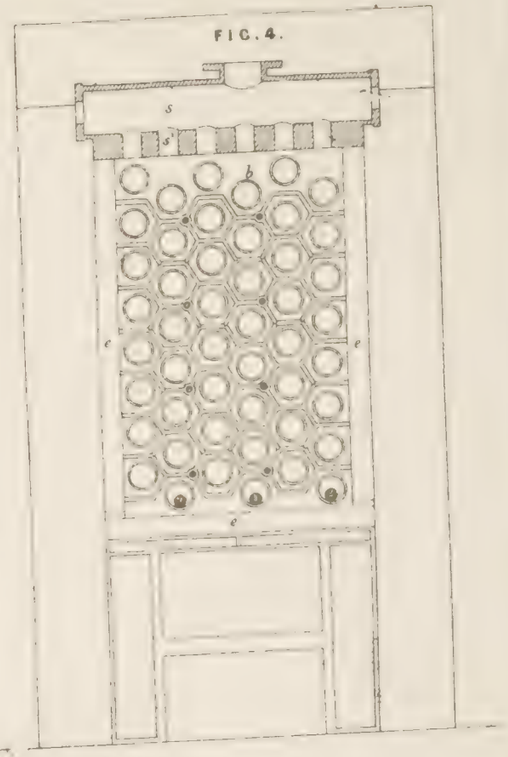


FIG. 5.

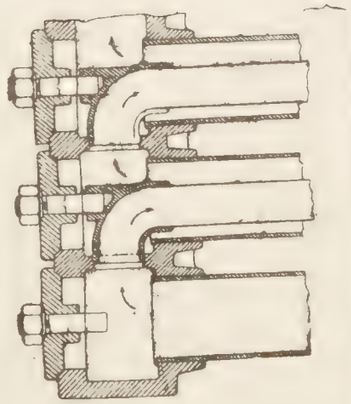


FIG. 5a

FIG. 6.

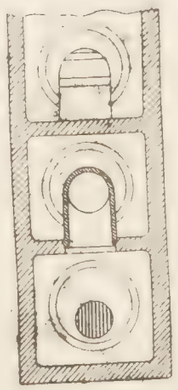


FIG. 7.

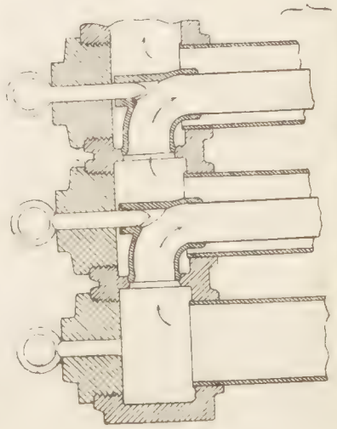


FIG. 8.

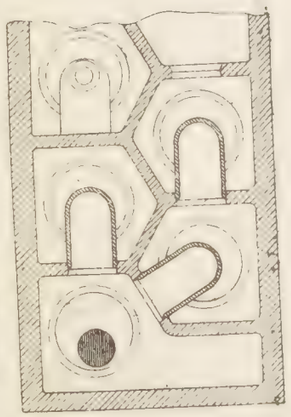


FIG. 9.

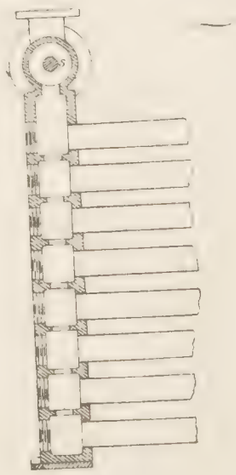
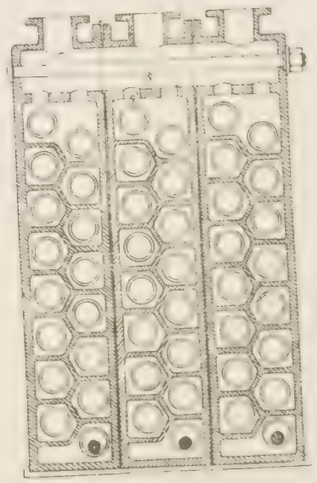


FIG. 10.



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A.D. 1873. Feb. 4. No. 412
SIXON'S SPECIFICATION

(4 SHEETS)
SHEET 1

Longitudinal Section

FIG. 1.

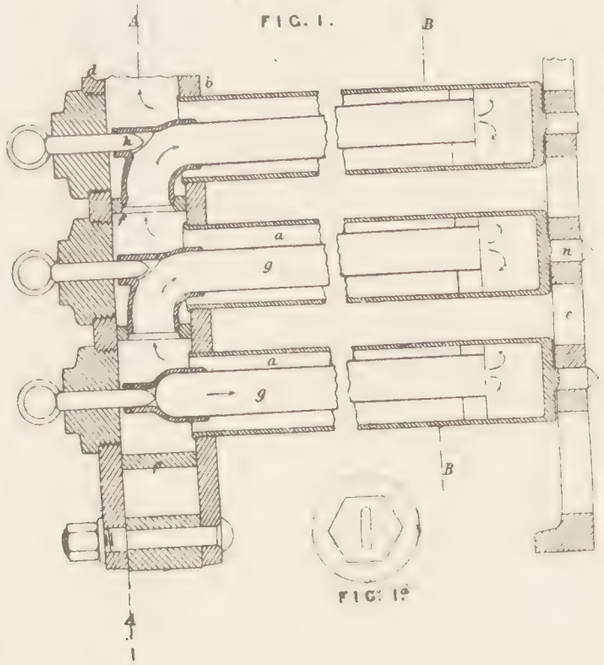
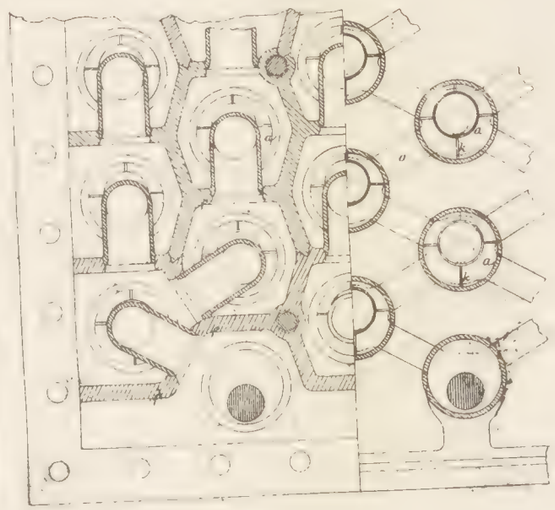


FIG. 1a

Transverse Section at A.A.

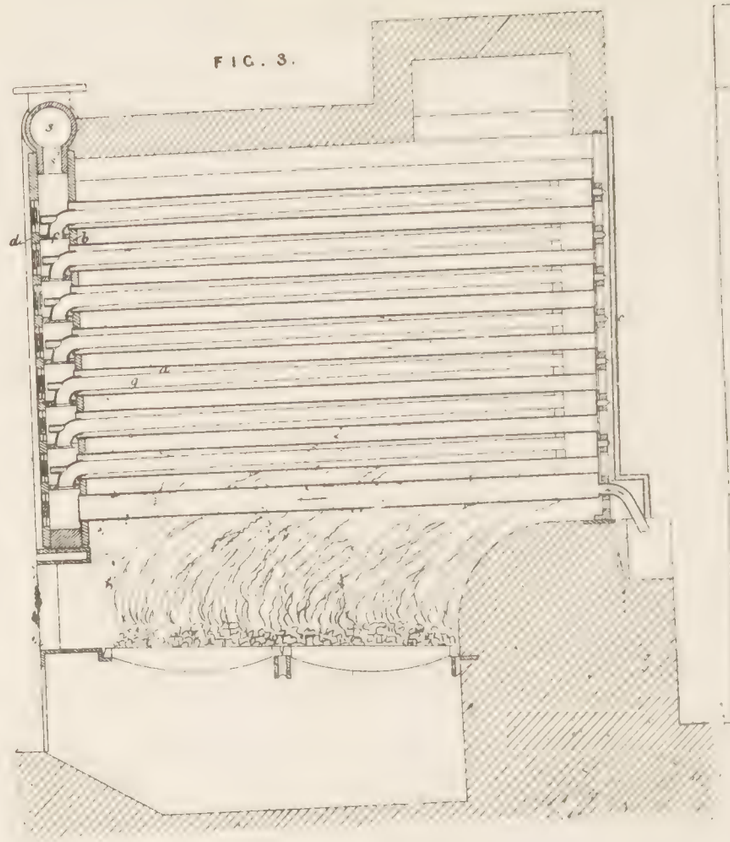
FIG. 2.

Transverse Section at B.B



Longitudinal Section.

FIG. 3.



Sectional Front View.

FIG. 4.

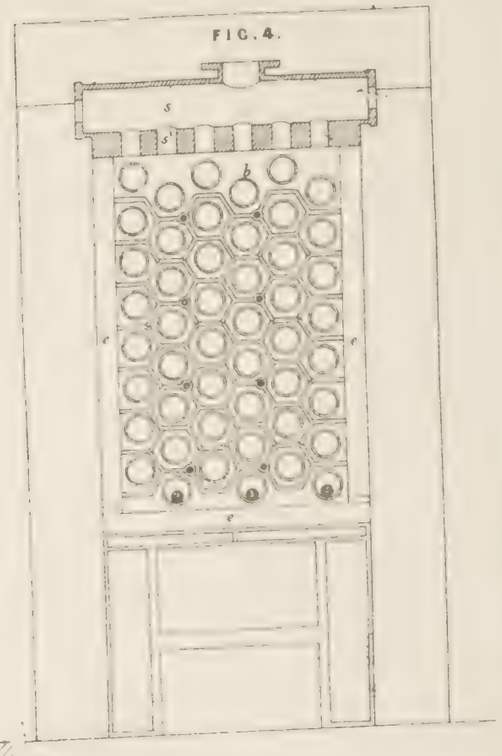


FIG. 5.

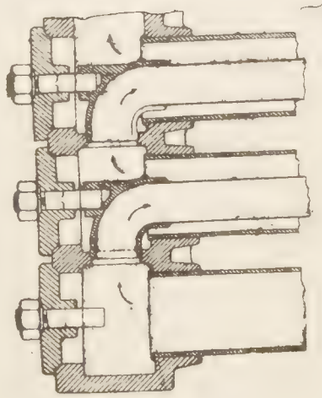


FIG. 5a

FIG. 6.

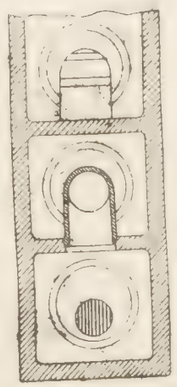


FIG. 7.

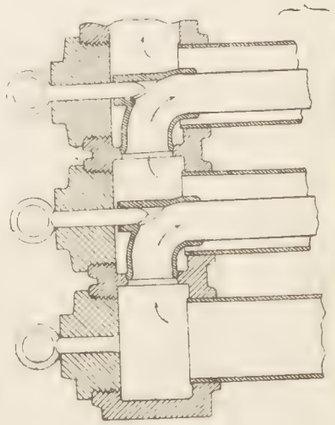


FIG. 8.

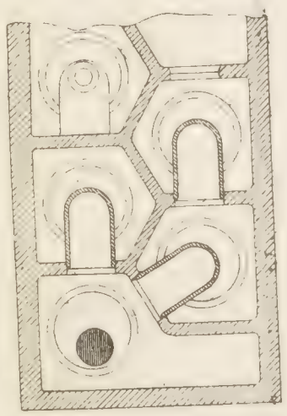


FIG. 9.

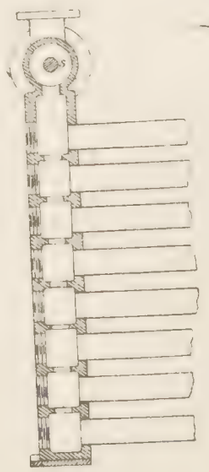
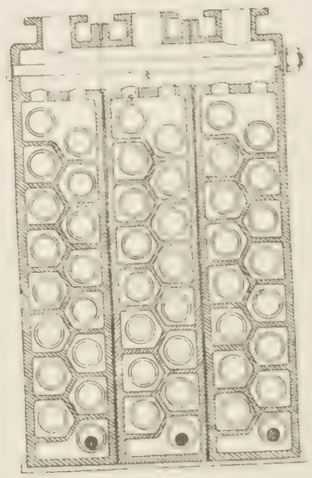


FIG. 10.



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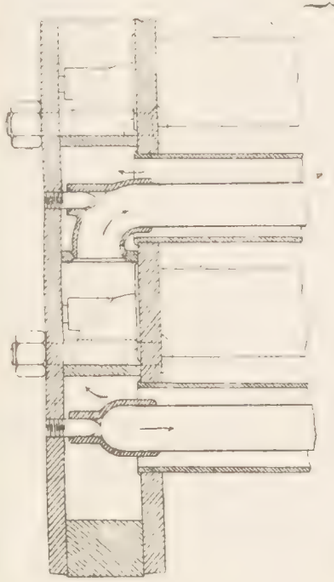
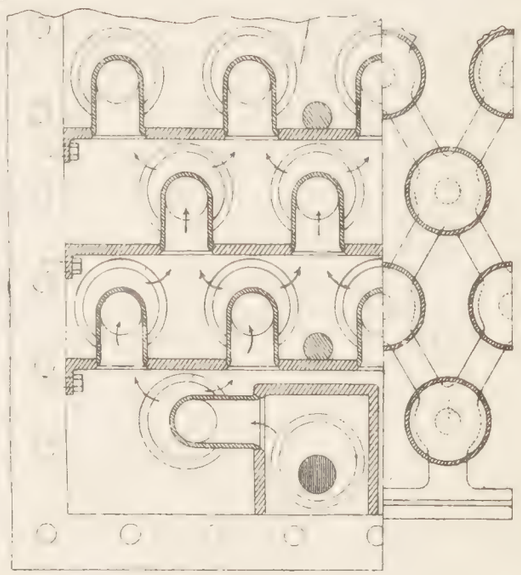
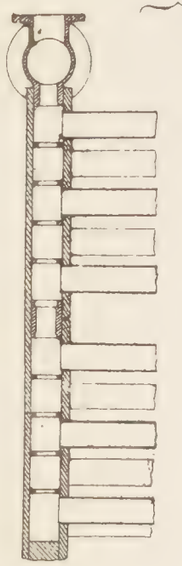
Longitudinal Section.
FIG. 11.



Transverse Section.
FIG. 12.



Longitudinal Section.
FIG. 13.



Transverse Sections.
FIG. 14.

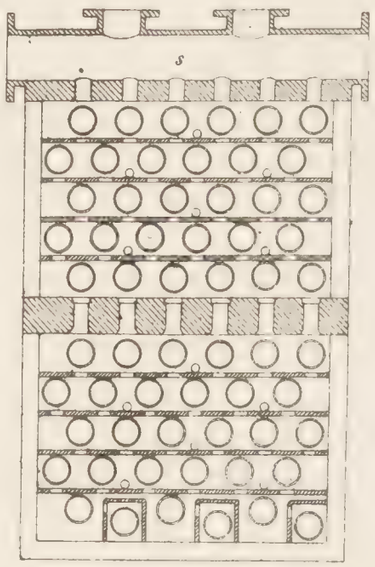
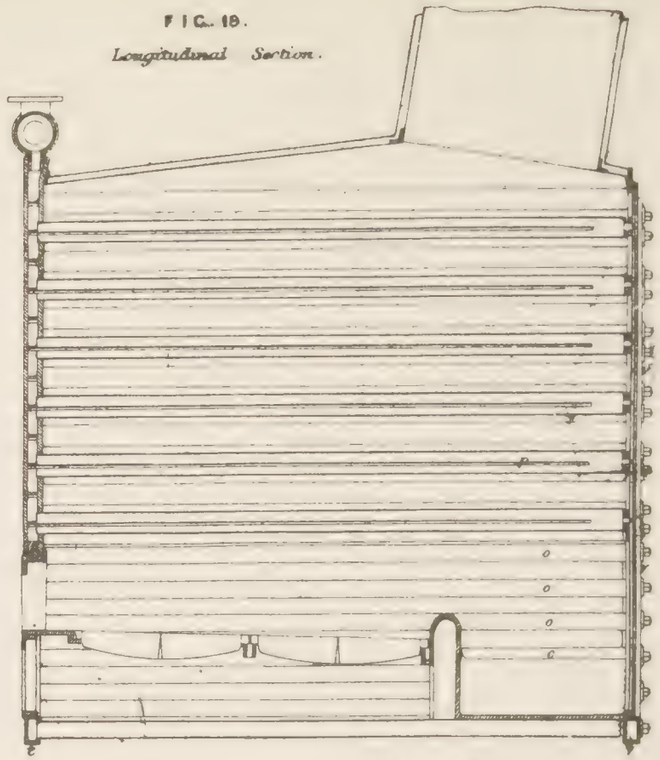
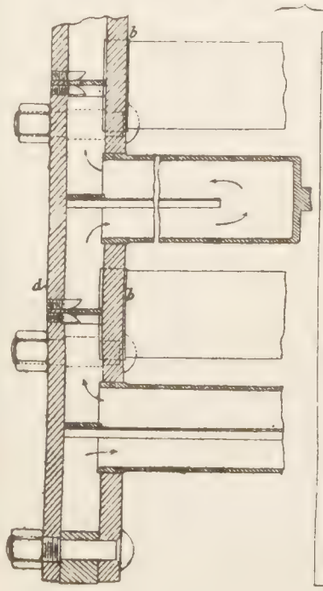


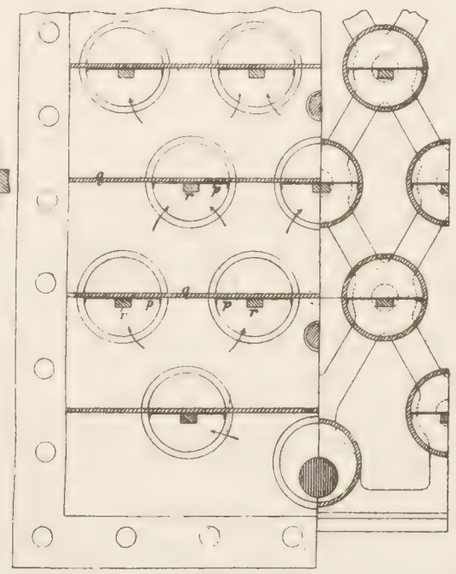
FIG. 19.
Longitudinal Section.



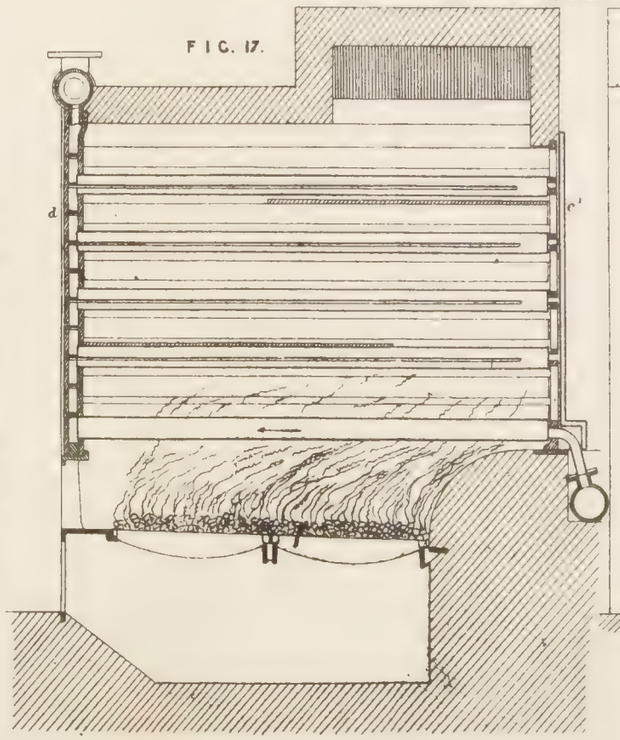
Longitudinal Section.
FIG. 15.



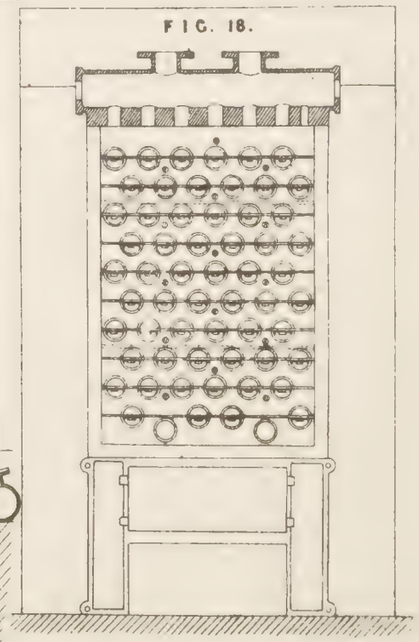
Transverse Section.
FIG. 16.



Longitudinal Section.
FIG. 17.



Transverse Section.
FIG. 18.



Sections.
through the communicating Chamber. through the tubes.
FIG. 20.

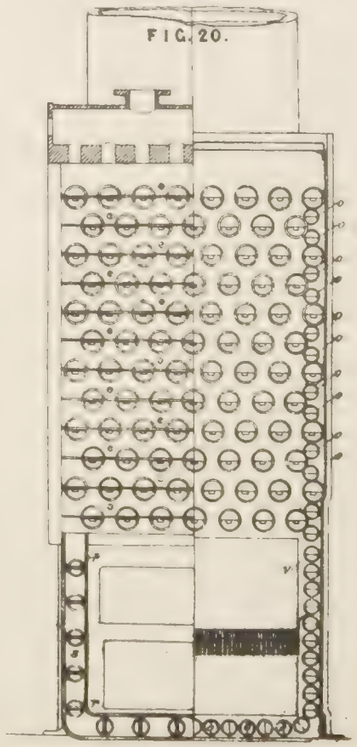


FIG. 21.
Longitudinal Section.

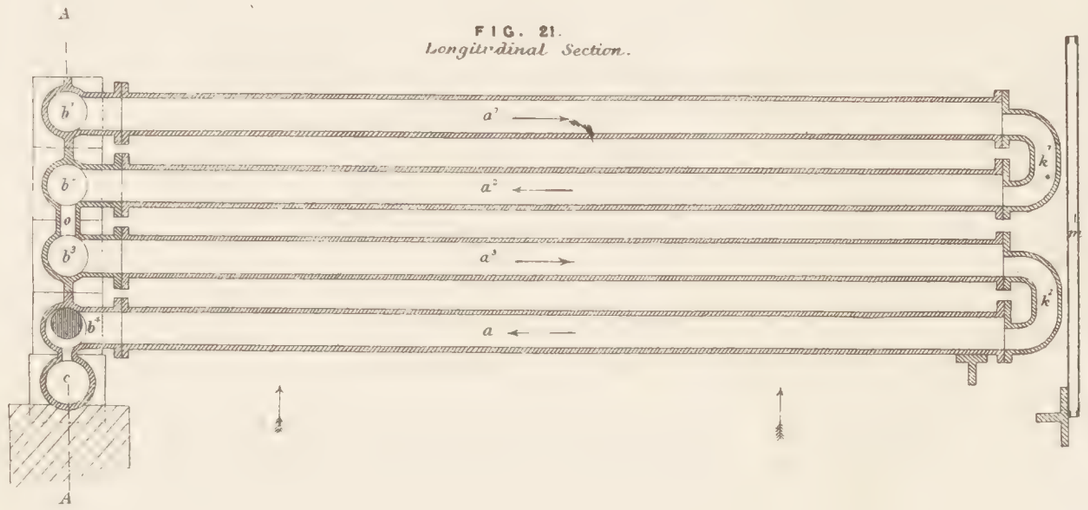


FIG. 22.
Transverse Section at AA.

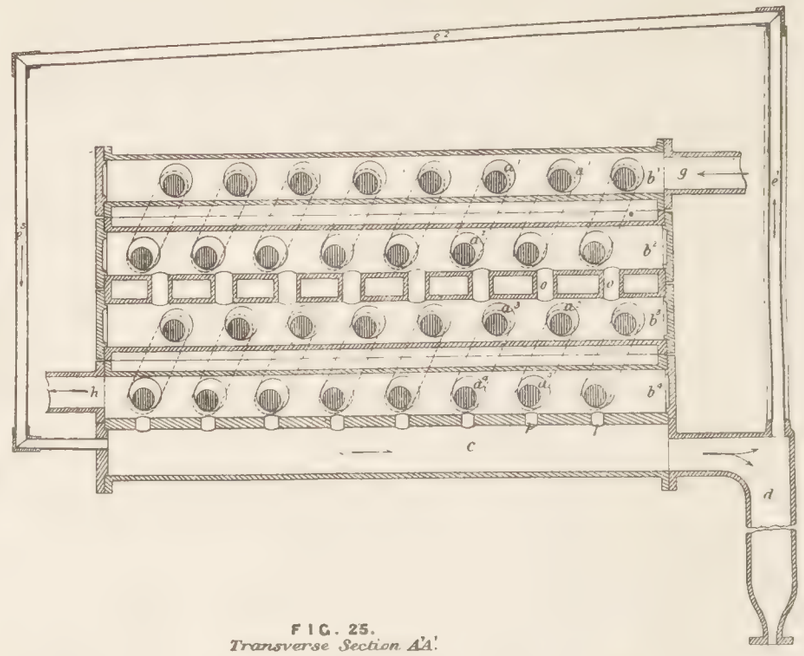


FIG. 23.
End Elevation.

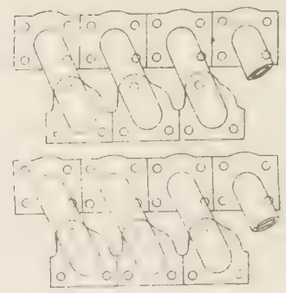


FIG. 24.
Longitudinal Section.

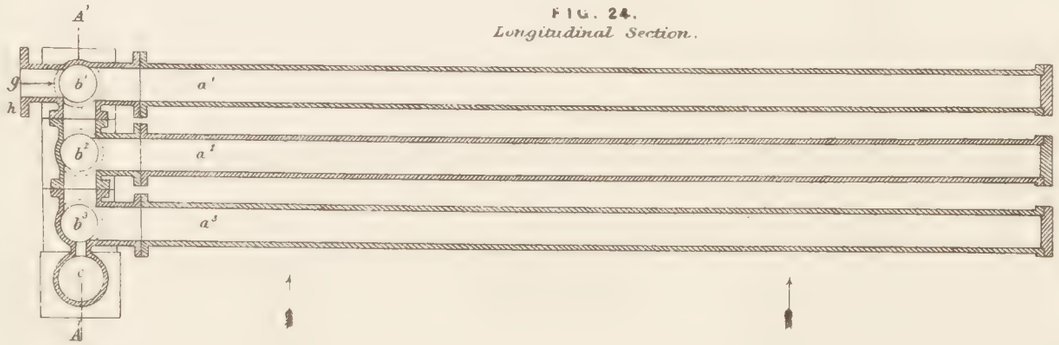


FIG. 25.
Transverse Section A'A'.

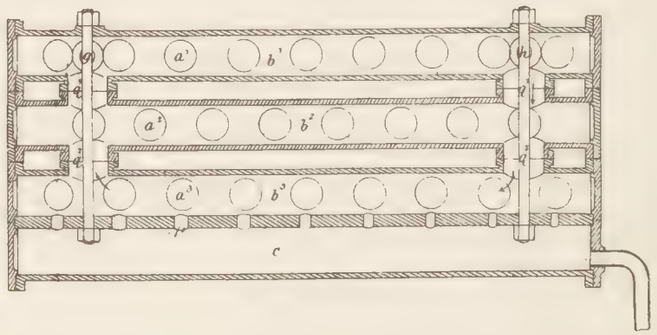


FIG. 26.
End Elevation.

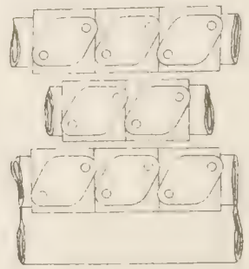


FIG. 27.
Longitudinal Section.

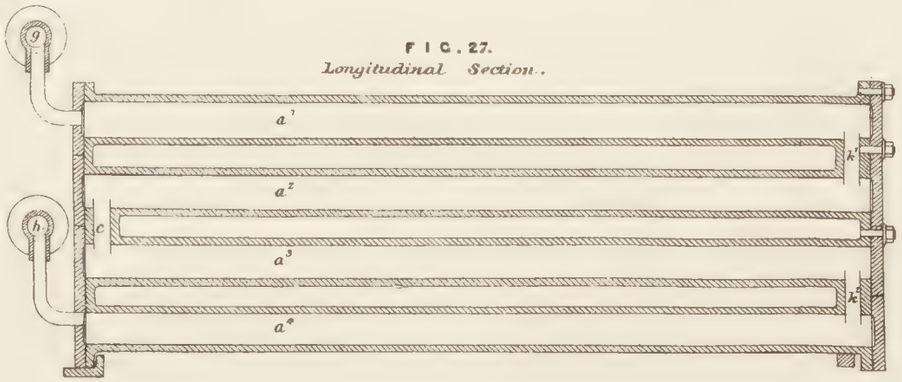


FIG. 28.
Transverse Section.

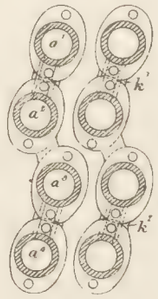
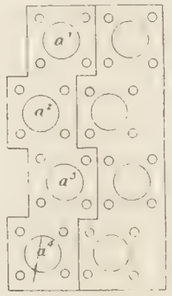


FIG. 29.
Front end Elevation.



The filed drawing is not colored.

Drawn on Stone by Malby & Son.

London: Printed by George Edward Eyre and William Spottiswoode,
Printers to the Queen's most Excellent Majesty. 1873.

FIG. 30.

Longitudinal Section.

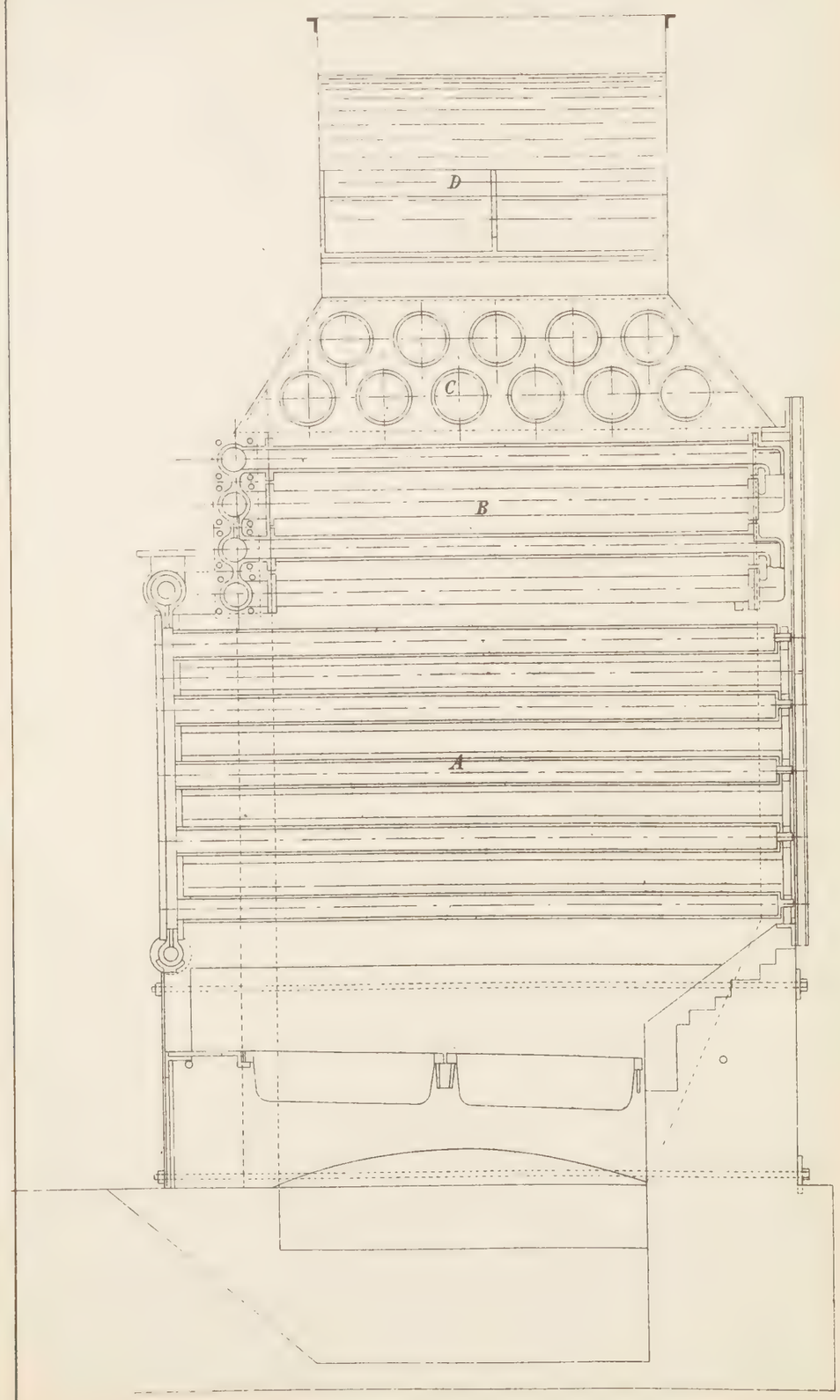


FIG. 31.

Transverse Section.

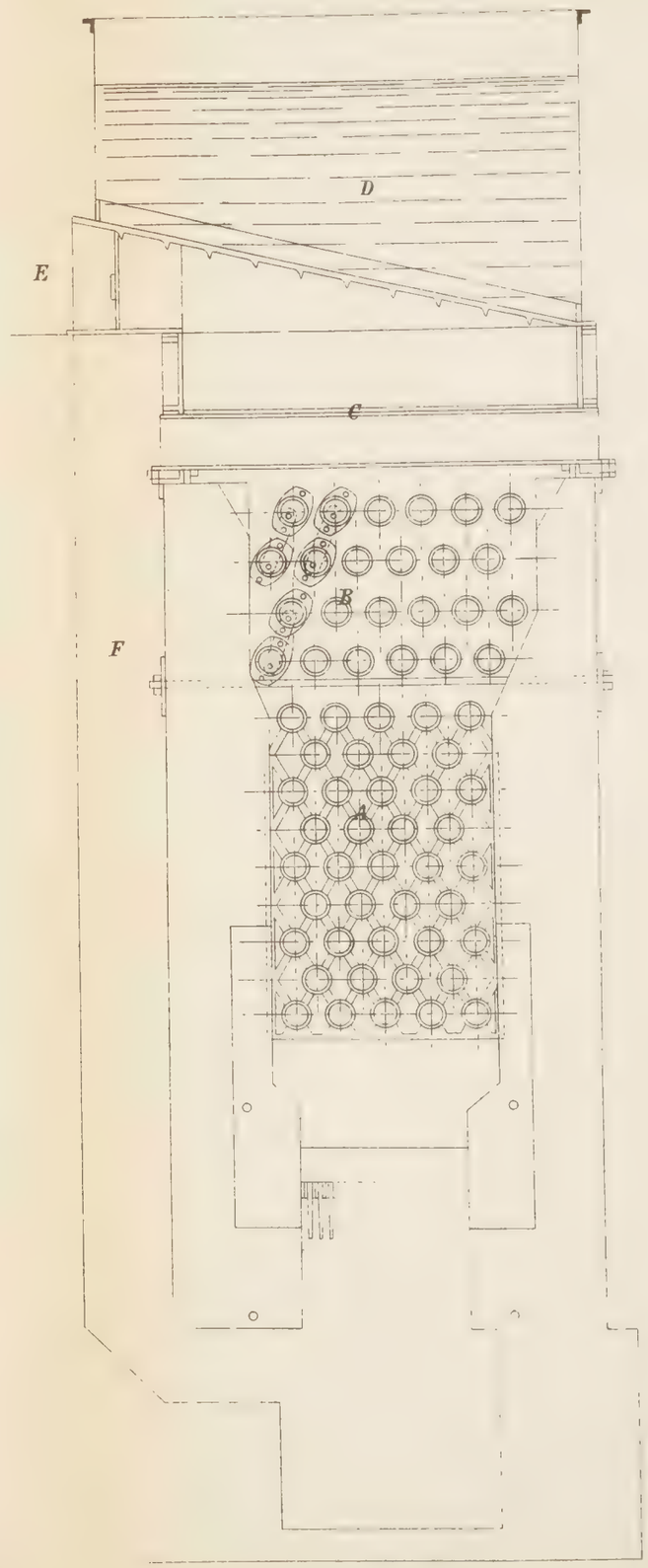
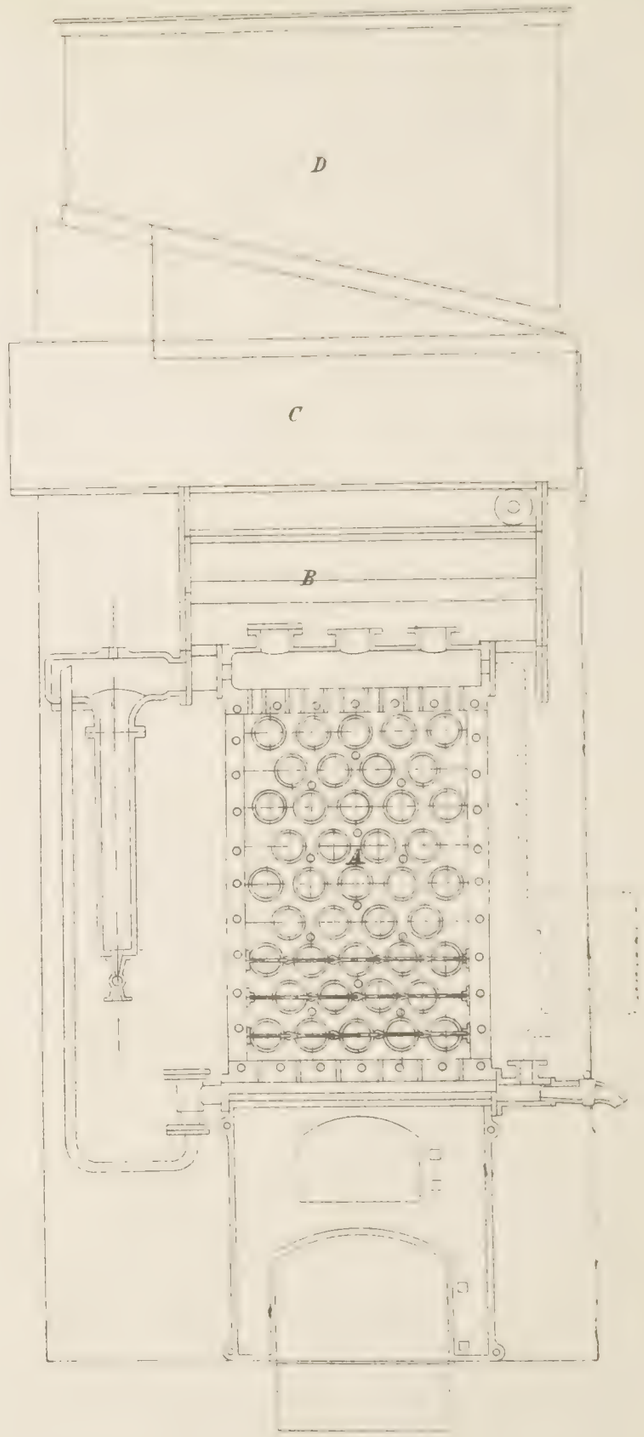


FIG. 32.

Front Elevation and Section through the Communicating Chamber.



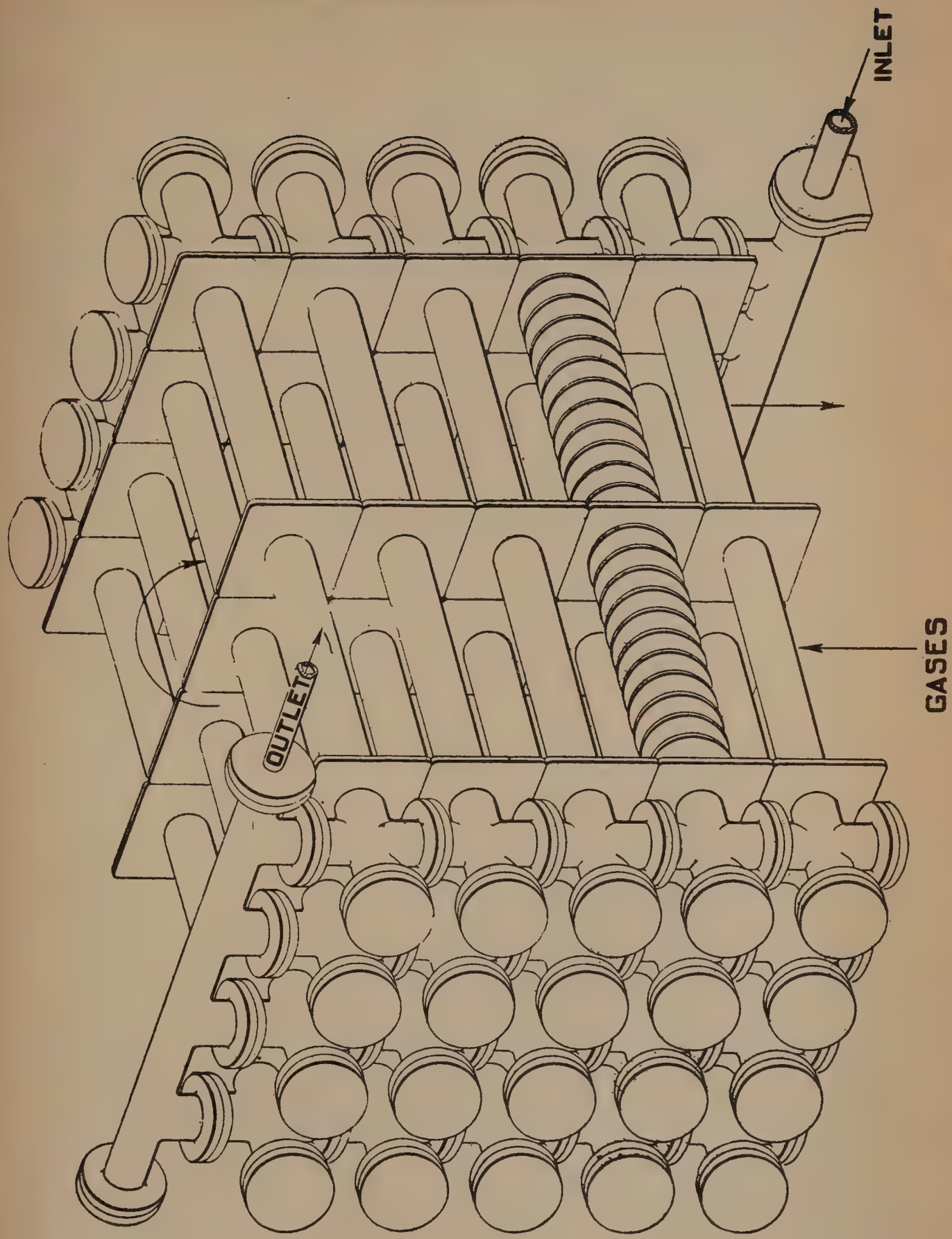
The filed drawing is partly colored.

LONDON Printed by GEORGE EDWARD EYRE and WILLIAM SPOTTISWOODE
Printers to the Queen's most Excellent Majesty 1873

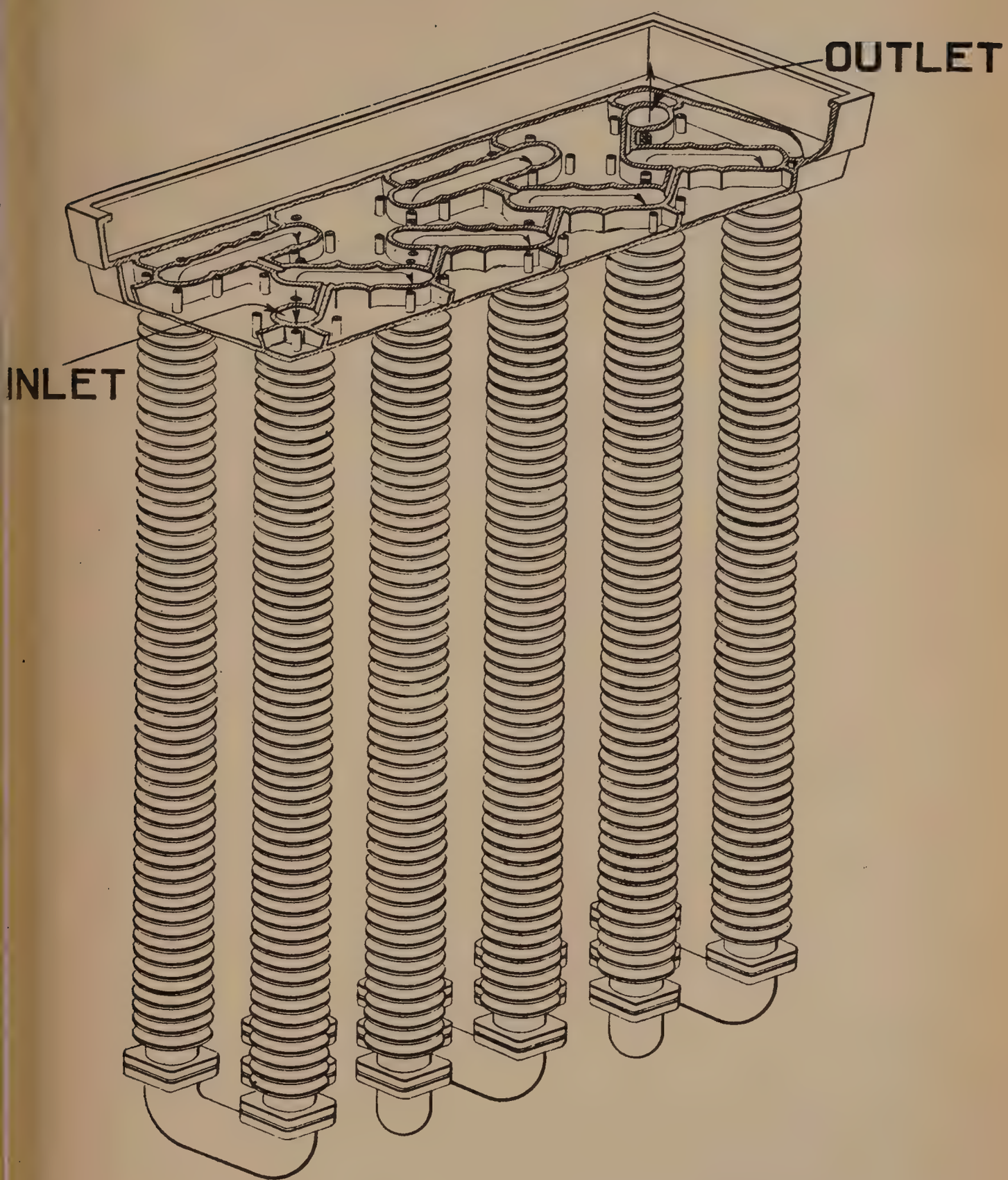
Drawn on Stone by Malby & Sons

DEFENDANT'S EXHIBIT L.

DIETRICH FRENCH PATENT No. 237,583

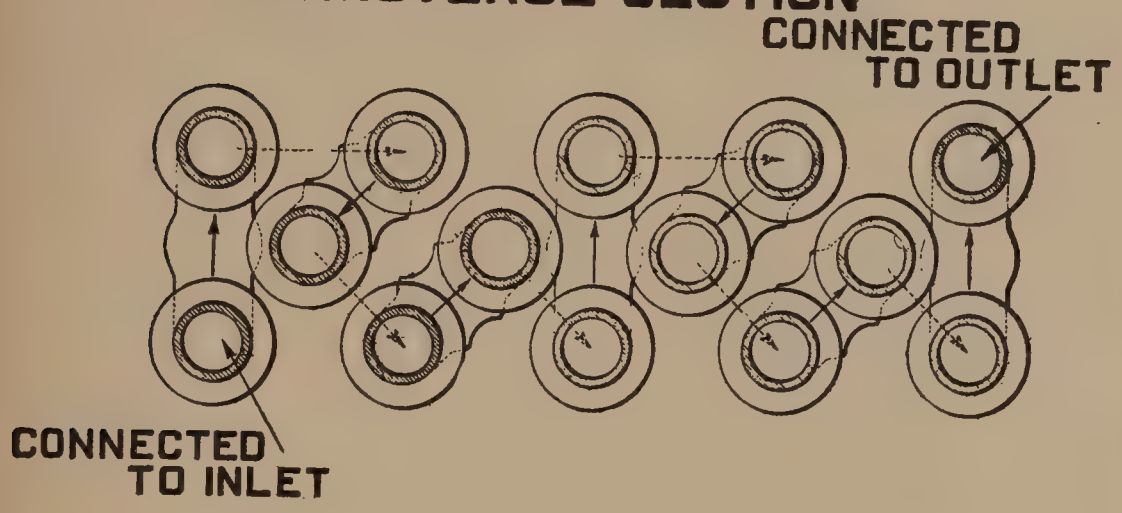


DEFENDANT'S EXHIBIT M.



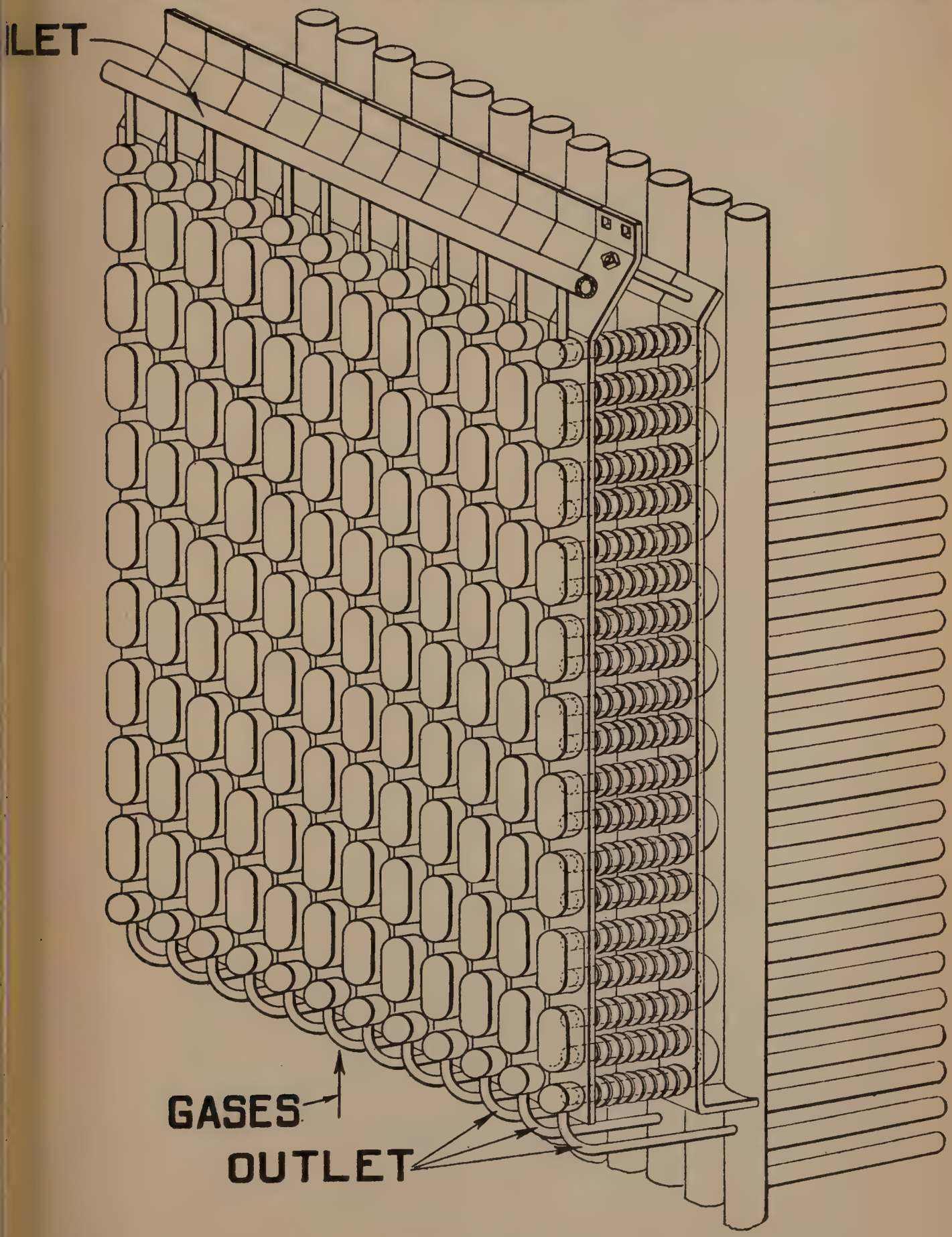
DEFENDANT'S EXHIBIT N.

KABLITZ PATENT Nº 886,516
TRANSVERSE SECTION



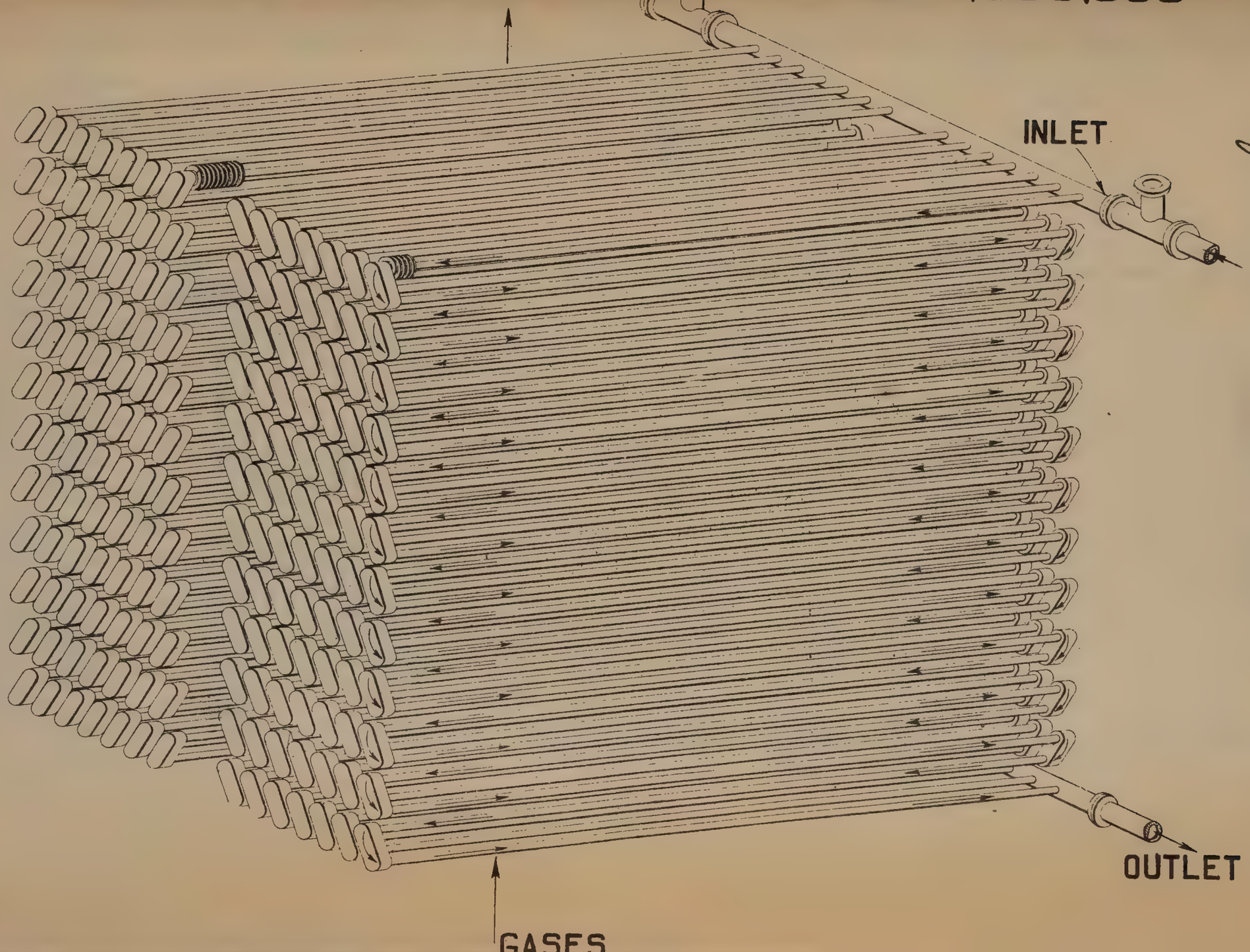
DEFENDANT'S EXHIBIT O.

FOSTER PATENT Nº1,239,377



BELL PATENT IN SUIT

No. 1,565,305

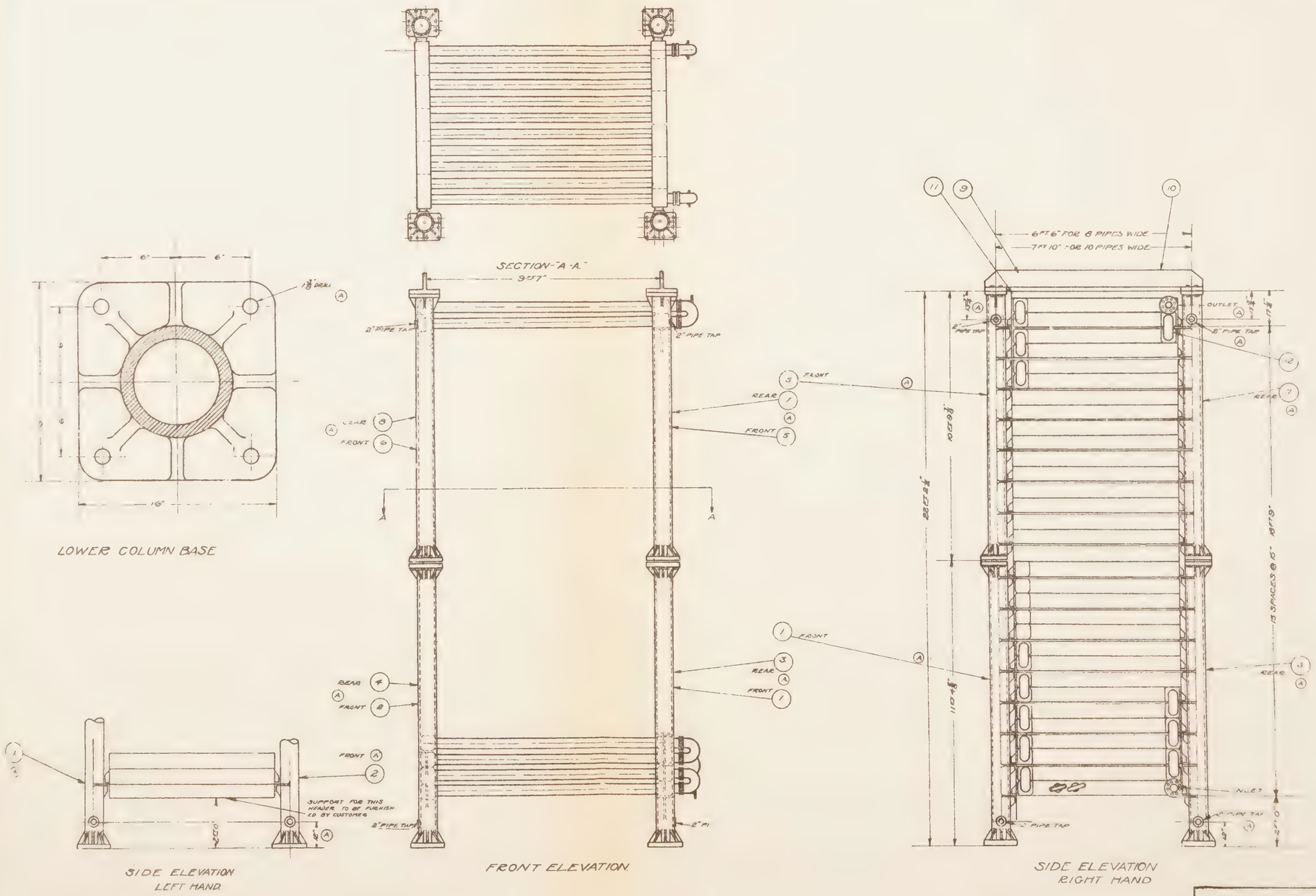


Defendants Exhibit P.

NOTES.

1. B.F.S. CO. FURNISHES TWO TYPE "OB" ECONOMIZERS EACH 32 SECTIONS, 8-9 FT 0" PIPES WIDE, ONE TYPE OB ECONOMIZER 32 SECTIONS, 10-9 FT 0" PIPES WIDE AND 12 CAST IRON COLUMNS WITH CAST IRON TIE BARS.
2. B.F.S. CO. DOES NOT FURNISH ANY FOUNDATIONS BELOW FLOOR LINE, BRICKWORK, FLUE WORK OR ANY OTHER MATERIAL NOT INCLUDED IN NOTE #1.
3. EXTEND ALL FOUNDATIONS TO SUITABLE FOOTINGS.
4. BUILD ALL BRICKWORK OF GOOD, SOUND RED BRICK, LAID NEAT FLUSH IN LIME AND CEMENT MORTAR.
5. COLUMNS SHOULD BE PROTECTED FROM HOT GASES.
6. APPROXIMATE WEIGHT OF ONE EMPTY SECTION: 8 PIPES WIDE 2700#, 10 PIPES WIDE 3600#

DEFENDANT'S EXHIBIT V.



NO. REQD	NAME OF PART	MATL	MARKS	DRAWING NOS. & REMARKS
16	100 BENDS			THIMBLES
10	1 TIE RAILS		ITEM #1	THIMBLES
9	"		" #2	
9	COL. NO. REAR UPPER	L.H.	FIG. #4	HISI
7	"	R.H.	" 3	"
6	" FRONT UPPER	L.H.	4	"
6	"	R.H.	3	"
4	" REAR LOWER	L.H.	2	"
4	"	R.H.	1	"
4	" FRONT LOWER	L.H.	2	"
4	"	R.H.	1	"

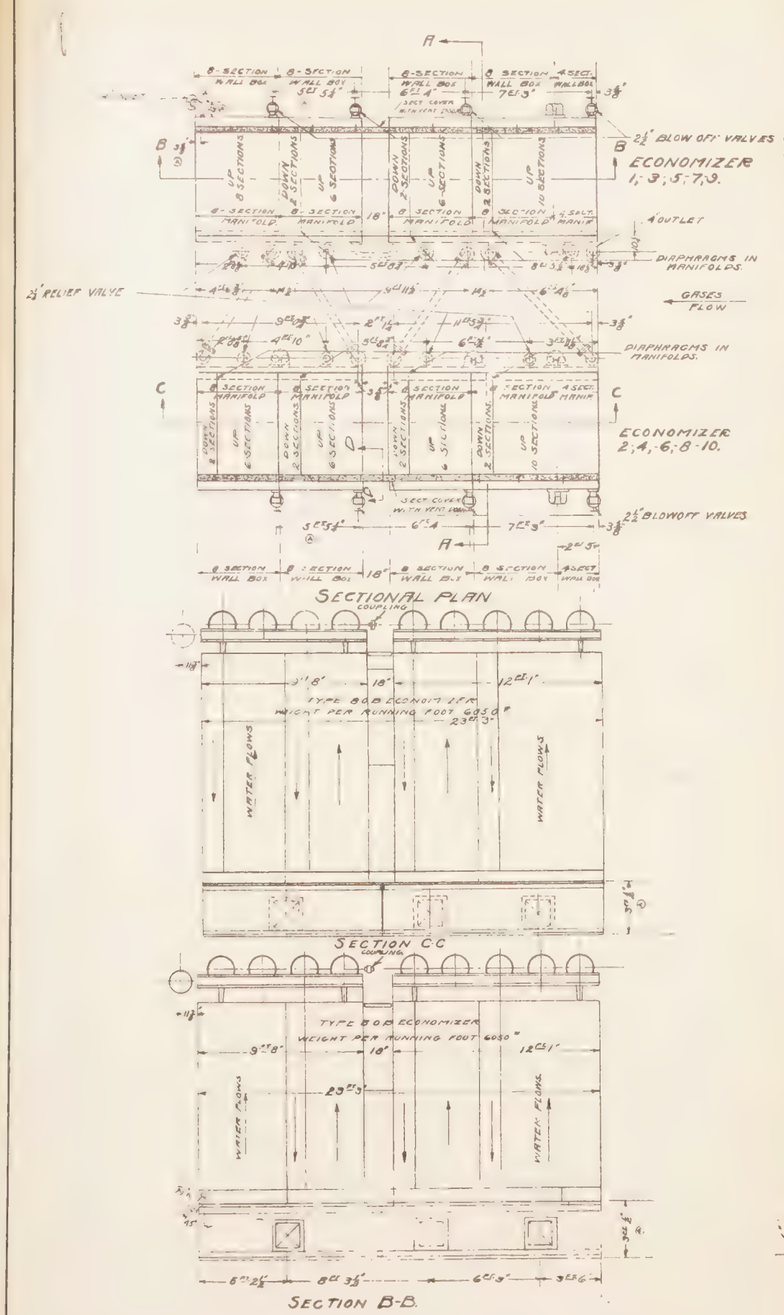
MATERIAL LIST FOR APPARATUS

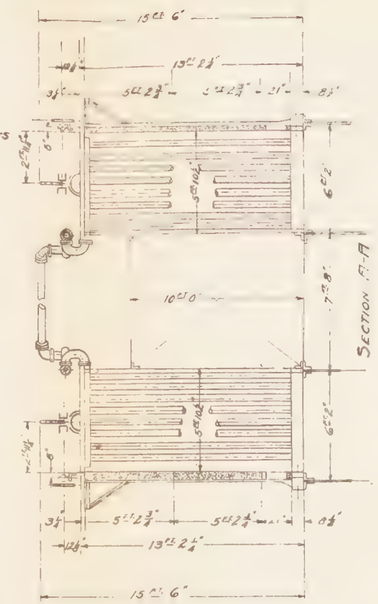
BARRET MFG CO.
NEW YORK, N.Y.
PROPOSED
ECONOMIZER ARRANGEMENT.

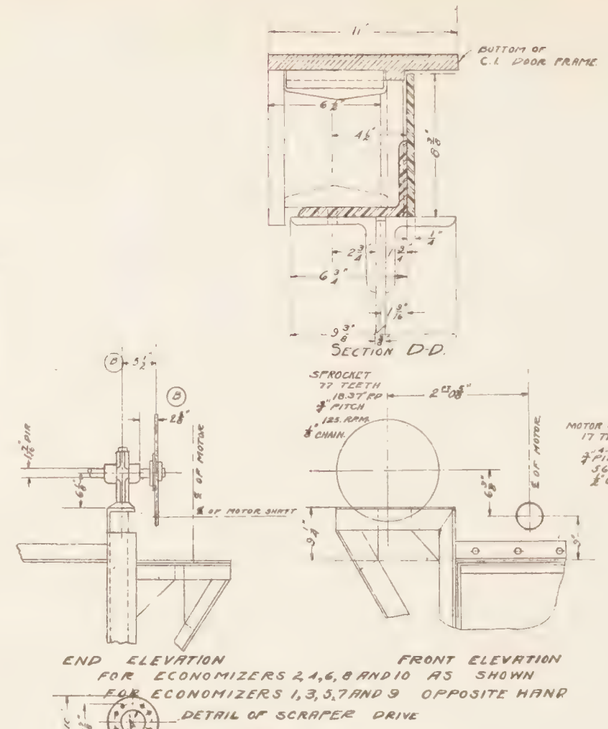
THIS DRAWING IS THE PROPERTY OF
B. F. STURTEVANT CO.
HYDE PARK, BOSTON, MASS.
AND SUBJECT TO RETURN UPON REQUEST.
IT IS TO BE USED ONLY FOR THE PURPOSE FOR WHICH IT WAS EXPRESSLY LOANED, AND NOT TO BE USED IN ANY WAY DETRIMENTAL TO THE INTERESTS OF THE COMPANY

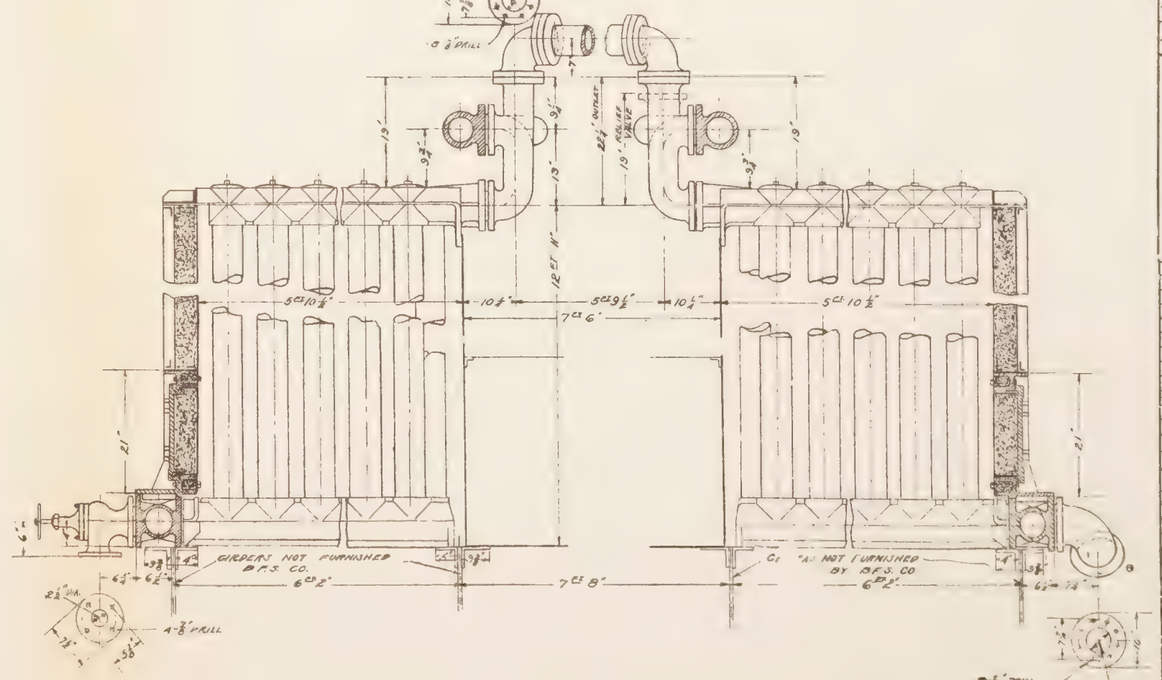
COMMENCED M.F.S. DATE 8-7-16 | CHECKED M.F.S. DATE 12-11-16
TRACED M.S.S. DATE 7-17 | APPROVED C.L.S. DATE 7-13
FOREMAN | Traced from C19-9670
CUSTOMER'S NO.
REPORT NO. | SCALE 3/4" = 1'-0"
ORDER NO. 2- | DWG. NO. C 5 5

C15-5088-P









NOTES

1. B.F.S. CO FURNISHES ECONOMIZER, EACH ARRANGED IN TWO GROUPS OF 36 SECTIONS EACH AS SHOWN COMPLETE WITH FRONT SECTIONAL COVERS, INSPECTION DOORS, SOOT PIT DOORS AND FRAMES, COVER PLATES, AND FILLER ANGLE IN EXPANSION SPACE.
2. B.F.S. CO DOES NOT FURNISH ANY OTHER MATERIAL INCLUDING ALL STRUCTURAL STEEL FOUNDATIONS ETC.
3. B.F.S. CO. FURNISHES PRESSURE PARTS ONLY ON ORDER #443653
4. B.F.S. Co FURNISHES SECTIONS ONLY ON ORDER #446779.
5. B.F.S. CO FURNISHES SECTIONS ONLY ON ORDER #448083
6. B.F.S. CO FURNISHES SECTIONS ONLY ON ORDER #450015.
7. B.F.S. CO FURNISHES SECTIONS ONLY ON ORDER #452418.
8. B.F.S. Co FURNISHES SECTIONS ONLY ON ORDER #459189

DEFENDANT'S EXHIBIT W.

ORDER NUMBER	REPORT NUMBER	CUSTOMER'S ORDER NUMBER	CUSTOMER	NO REQ	DR BY OR BY	REMARKS OR MOTOR THAT DRIVES
283285	CHICAGO 33750A.		INDIAN GAS & ELEC. CO. WINDSOR POWER STATION SULLIVAN, IND. & MARION SARGENT & LUNDY ENG.	5	[illegible]	1-2
295272	CHICAGO 37139		INDIANA POWER STA. OF BRECKINRIDGE IN INDIANA SARGENT & LUNDY ENG.	3	[illegible]	1-2
305321	CHICAGO 38343		ANTHRACITE ELEC. CO. WINDSOR POWER STATION JEFF. CO. PA. & MARION SARGENT & LUNDY ENG.	4	[illegible]	1-2
307306	CHICAGO 38511		[illegible] ELEC. CO. WINDSOR POWER STA. BEAVER BOTTOM, W. VA. THOMSON & SHOOK ENGS.	3	[illegible]	1-2
443653			[illegible] GAS & ELEC. CO.	2	[illegible]	3
446779	N.Y. 50495	88-7423	[illegible] ELEC. CO. WINDSOR POWER STA. BEECH BOTTOM, W. VA.	2	HND. 4-1-27 JCS.	4
448083	N.Y. 50689H	88-17[illegible]	BEECH BOTTOM POWER CO. BEECH BOTTOM, WEST VIRGINIA	2	[illegible] CWS.	5
450015	N.Y. 51019	88-14614	BEECH BOTTOM POWER CO. BEECH BOTTOM, WEST VIRGINIA	2	JCD 6-20-27 BCM	6
452418	N.Y. 51407	88-19668	BEECH BOTTOM POWER CO. BEECH BOTTOM, W. VA	2	[illegible] JCF	7
459189	N.Y. 52488	88-1625	Beech Bottom Power Co. Beech Bottom W. Va	2	[illegible] JCF	8

NO. REQ'D	NAME OF PART	MAT'L	PAT. NO.	DRAWING NOS & REMARKS
	MATERIAL LIST FOR ____ APPARATUS			

REFERENCE DRAWINGS: C15-5088; SERIES; 13-18162; SERIES; 13-9334; SERIES

REQD DRAWINGS: C15-7822; SERIES

CHANGES: (A) [illegible]; (B) [illegible]

PROPOSED ECONOMIZER SETTING AND DIAGRAM OF CIRCULATION

THIS DRAWING IS THE PROPERTY OF
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HYDE PARK, BOSTON, MASS.
AND SUBJECT TO RETURN UPON REQUEST.
IT IS TO BE USED ONLY FOR THE PURPOSE FOR WHICH IT WAS EXPRESSLY LOANED AND NOT TO BE USED IN ANY WAY DETRIMENTAL TO THE INTERESTS OF THE COMPANY

COMMENCED M.T.S.	DATE 12-4-16	CHECKED	DATE
TRACED TO	DATE 2-10-16	APPROVED	DATE
FOREMAN A.W. KNIGHT			
CUSTOMER'S			
FOLDER No		SCALE	

Dfh 4 X
11-15-27

Rundschau.

Für die Durchführung von **Knickversuchen mit geraden Stäben**, bei denen diejenige Last ermittelt werden muß, bei welcher der Probestab gerade auszuknicken beginnt, hat Prof. C. A. M. Smith vom East London College der University of London ein sehr **einfaches Meßgerät** erdacht[1]), das von E. Tyndall Cook in Leyton gebaut worden ist. Das Gerät, Fig. 1, besteht aus zwei Bronzeplatten *a*, die mit Hülfe von je 3 unter 120° gestellten Schrauben *b* an dem Probestab *c* befestigt werden. Zwischen den Platten sind drei genau gleiche zu Schraubenfedern zusammengewickelte Metallstreifen parallel zur Achse des Probestabes ausgespannt, die in der Mitte kleine Spiegel *d* tragen. Läßt man auf jeden Spiegel ein Strahlenbündel fallen, dessen Bild gegen entsprechend geteilte Schirme zurückgeworfen wird, so werden, da bei Verkürzung des Probestabes die Metallstreifen verdreht werden, bei einem Druckversuch die drei Bilder längs der Teilungen solange gleichmäßig fortwandern, wie der Probestab genau gerade bleibt, während beim Beginn des Ausknickens sofort das eine Spiegelbild den andern weit vorauseilt. Da in dieser einfachen Form das Eichen des Meßgerätes Schwierigkeiten macht, so weicht die praktische Ausführung, Fig. 2, hiervon insofern ab, als die oberen Enden der in zwei verschiedenen Richtungen gewickelten Streifen *g* nicht unmittelbar mit der oberen Platte *a*, sondern mit gerade geführten Kolben *e* verbunden sind, die mit Hülfe einer mit Mikrometerteilung versehenen Ueberwurfmutter *f* verstellt werden können. Vor Beginn einer Versuchreihe braucht daher nur für jeden Spiegelträger besonders diejenige Längenänderung bestimmt zu werden, die der Einheit der verwendeten Teilung auf dem Schirm entspricht. Das Gerät ist in dieser Form für alle Arten von Festigkeitsversuchen verwendbar, insbesondere auch für die genaue Bestimmung von Elastizitätsziffern bei Zug- und Druckversuchen; es liefert hierbei für jede Belastung sofort drei Ablesungen, aus denen ohne weiteres ein sehr genaues Mittel genommen werden kann.

Fig. 1.

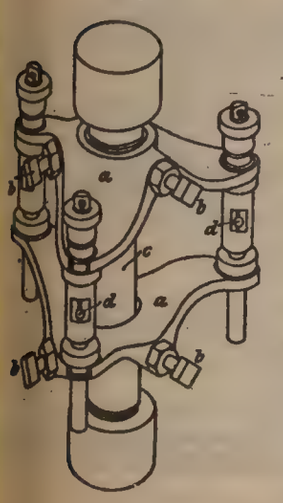
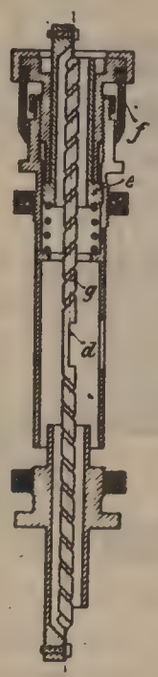


Fig. 2.



Vor einiger Zeit wurde an dieser Stelle über Versuche mit einem Rauchgasvorwärmer von J. Krüger & Co. berichtet[2]). Bemerkenswert hierbei ist der hohe Wärmeübertragungskoeffizient $k = 14{,}2$ WE-st für 1 qm Heizfläche bei 1° mittlerem Temperaturunterschied zwischen Rauchgas und Wasser. Mit diesem Werte sollte man aber nicht veranschlagen, weil alle Bedingungen selten günstig zusammentrafen, so die hohe Temperatur der Abgase bei verhältnismäßig hoher Gasgeschwindigkeit und kräftigem Ventilatorzug, ferner weil der Rauchgasvorwärmer knapp bemessen und unmittelbar vorher gründlich gereinigt worden war. Unter ähnlichen Verhältnissen erzielte ich mit einem Rippenrohrvorwärmer von 165 qm bei der Aktien-Gesellschaft »Textil« in Riga einen Wert von $k = 11$ im Mittel und bei der Aktien-Gesellschaft Ludwig Rabeneck in Moskau bei einem Vorwärmer von 385 qm anfänglich den Wert $k = 14$ und später $k = 10$.

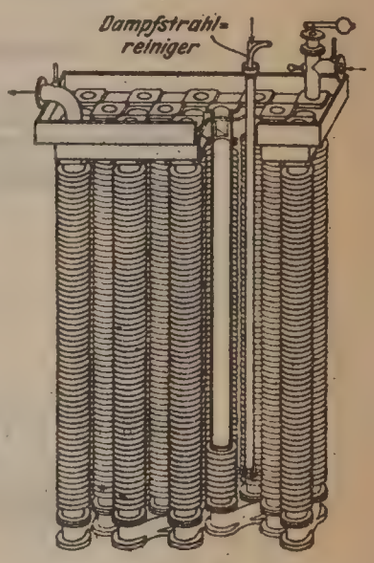
Ich habe bereits früher eine ganze Reihe von Versuchen verschiedener bekannter Fachleute zur Bestimmung des Wärmeübertragungskoeffizienten zusammengestellt[3]) und sie bis heute ergänzt, wobei ich als brauchbare Mittelzahl im Dauerbetriebe $k = 7$ gefunden habe; ferner fand ich, daß 1° Wassererwärmung $2^1/_2$° Gasabkühlung entsprechen.

Ein **Rippenrohr-Rauchgasvorwärmer der Bauart Kablitz**[1]) ist in Fig. 3 dargestellt.

Für die Rohre ist Gußeisen verwendet, weil es den chemischen Einwirkungen am meisten widersteht und weil es am billigsten ist. Durch Rippenrohre ist eine große Aufnahmefläche für die Wärme aus den Gasen geschaffen; der Wärmeaufnahmekoeffizient aus den Gasen (k = rd. 20 als größter Wert bei etwa 10 m Geschwindigkeit) ist gering, und außerdem treffen die Gase nicht alle Rohrteile gleich kräftig. Dagegen kann die Fläche für die Wärmeabgabe an das Wasser mehrfach kleiner sein wegen des weit größeren Uebertrittskoeffizienten und der gleichmäßigen Bespülung durch Wasser (k = rd. 1000 als geringster Wert, s. »Hütte« 1905 Teil I S. 281). Die gasberührte oder Rippenrohrfläche sollte somit mindestens 1000:20 = 50 mal größer sein als die wasserberührte. Das Rippenrohr ist also für diesen Zweck besonders geeignet.

Fig. 3.

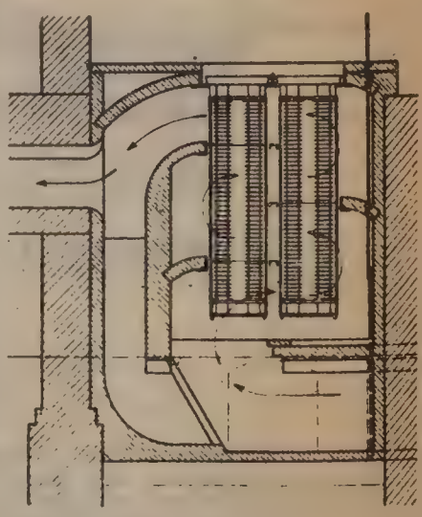
Rippenrohr-Rauchgasvorwärmer, Bauart Kablitz.



Das Wasser läuft bei diesem Vorwärmer durch ein Element von 14 Rippenrohren von je 2 m Länge, 100 mm l. Dmr. und 4 qm äußerer Rippenrohrfläche. Die Rohre werden alle nacheinander der entgegen dem Gasstrom vom Wasser durchströmt, um ein möglichst großes Temperaturgefälle an allen Stellen zu haben. Das ganze Element hat 55 qm gasberührte Heizfläche.

Alle 14 Rippenrohre sind mit ihrem oberen Ende am Verteilkörper hängend angeschraubt, der gleichzeitig eine luftdichte Kanalabdeckplatte mit allen Zugangsöffnungen bildet, so daß durch den Vorwärmer selbst keine kalte Luft nachgesogen werden kann. Dieser Verteilkörper verbindet je zwei Nachbarrohre miteinander durch sechs große Kanäle, während die andern Enden durch sieben Doppelkrümmer verbunden sind. Hierdurch ist eine freie Ausdehnung der Rippenrohre möglich. An dem einen Ende der Verteilplatte tritt von oben das kalte Wasser ein, durchströmt alle Rippenrohre, abwechselnd in ihnen auf und absteigend, und tritt dann erwärmt aus, jedoch immer entgegengesetzt der Richtung

Fig. 4.



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[1]) Engineering 21. August 1908.

[2]) Z. 1908 S. 1534.

[3]) s. Zeitschrift für Dampfkessel und Maschinenbetrieb 1907 Heft 9. Weitere Versuche sind angestellt von:

G. von Doepp, St. Petersburg, Zeitschrift der Wissenschaftlichen Gesellschaft der Technologen, Heft 12 vom Dezember 1907, S. 495: $k = 6{,}5$; die Versuche werden noch fortgesetzt und dürften im Laufe der nächsten Zeit veröffentlicht werden.

Schröder, Neuere Pumpmaschinen des Hamburger Wasserwerkes, Z. 1907 S. 1183 Zahlentafel 5: $k = 8{,}43$.

Blacher, Versuche an der Kraftzentrale der Straßenbahnen, Riga, Rigasche Industrie-Zeitung Nr. 21 vom 15. November 1907: $k = 4{,}23$; diese Versuche sind an demselben Gegenstrom-Rauchgasvorwärmer von uns am 5., 6. und 8. September 1908 nochmals als Dauerversuche von je 18 Stunden durchgeführt und haben $k = 4{,}49$, 4,70 und 4,73 ergeben.

[1]) D. R. P. Nr. 175600.

des Gasdurchflusses. Die sechs großen Wasserkanäle im Verteilkörper sind durch fünf kleine, geeignet bemessene Kanäle miteinander verbunden, um Gase und Dämpfe abzuführen.

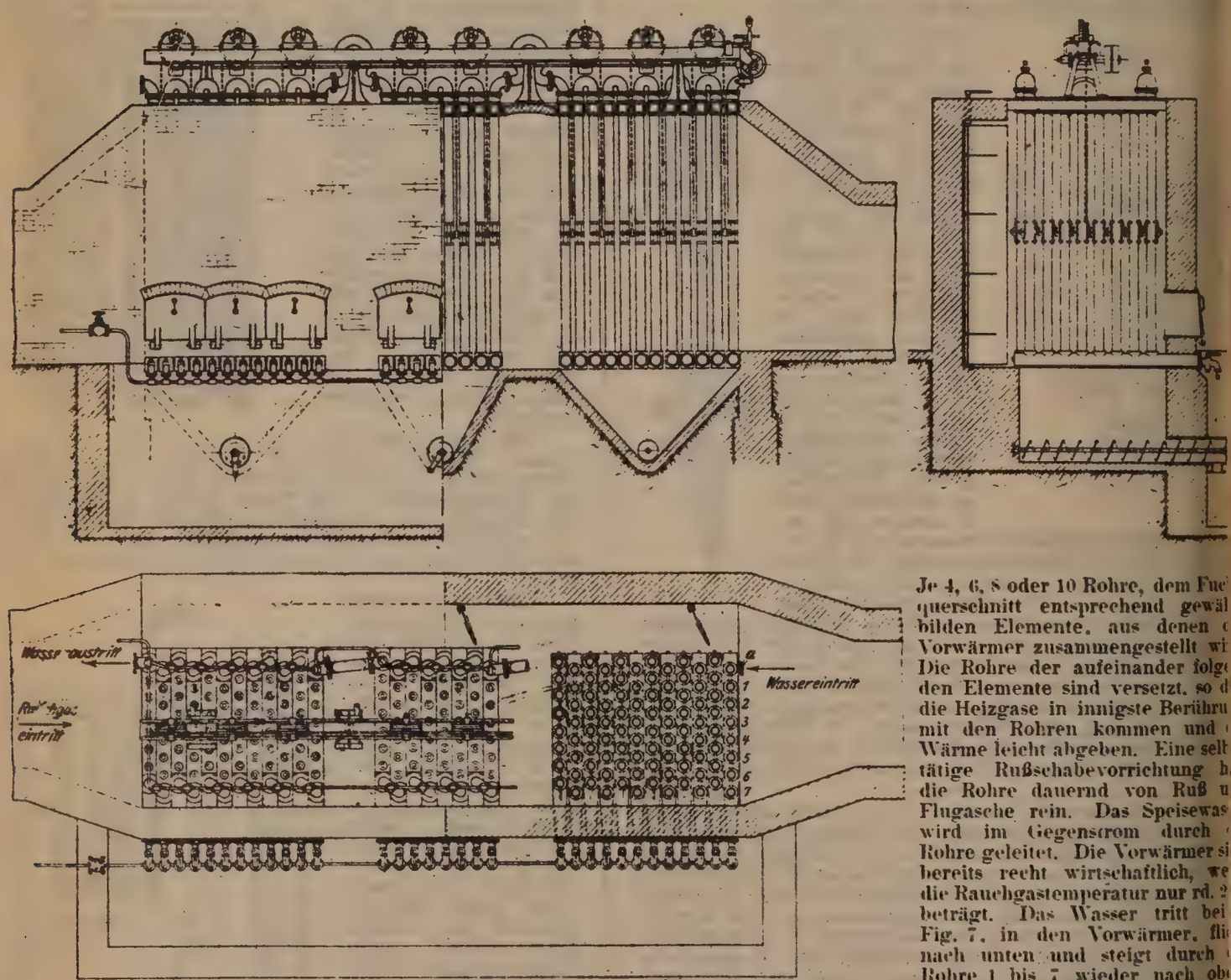
Die Befürchtung, daß die äußere Reinigung schwierig sein könnte, hat sich als hinfällig erwiesen, weil bei Gasgeschwindigkeiten von etwa 5 m/sk keinerlei Fremdkörper anhaften, bis auf den Ruß, der wie Schneeflocken an jeder beliebig gestellten Fläche haftet, aber bei 10 m Geschwindigkeit auch weggeblasen wird. Man hat es somit in der Hand, jede nennenswerte Rußbildung zu vermeiden, um so mehr, als eine Geschwindigkeit von 10 m/sk nur rd. 5 bis 7 mm Wassersäule verbraucht, weil die Rippen den Gasstrom nicht durchwirbeln, sondern in einzelne schmale Strähne zerschneiden und dadurch das erwünschte rasche Zuführen heißer Gase und das Abführen abgekühlter erzielt wird. Um die Rippenrohre bequem abblasen zu können, wird zwischen je vier Rippenrohren eine Dampfstrahlvorrichtung durch 5 im oberen Verteilkasten befindliche selbsttätig schließende Luken senkrecht eingeführt. Ein Element, das 2200 kg wiegt, braucht einen Raum von nur 1600×730 mm Grundfläche und 2400 mm Tiefe. Mehrere solcher Elemente werden nebeneinander gelegt, durch vierteilige Rohre untereinander verbunden und der Gasstrom zur Erzielung hoher Gasgeschwindigkeiten durch wagerechte Bleche mehrfach hin- und hergeführt; s. Fig. 4. Dabei ist jedes Element von 55 qm Heizfläche vom Nachbarelement unabhängig und kann mit einem Flaschenzug eingehängt und nach Lösung der Rohrverbindung und Umschalten herausgehoben werden. Wenn man die freie Stelle mit einem Bleche von 1600×730 mm abdeckt, so kann der Betrieb mit den andern Elementen weitergehen. Da sich die Rohre frei ausdehnen können und ein Element in der Mittagspause ausgewechselt werden kann, hängt man die Vorwärmer unmittelbar in den Fuchs, w durch Umgehungskanäle, Schieber usw. vermieden werd können.

Richard Kablitz, Riga.

Ein andrer **Vorwärmer** wird von der König Friedri August-Hütte, Potschappel bei Dresden, gebaut; s. Fig bis 7. Dieser Vorwärmer besteht aus glatten, senkrecht a geordneten gußeisernen Rohren, die in den erweitert Fuchs oder in einen Nebenkanal zwischen Kessel und Schor stein eingebaut werden. Die Anordnung richtet sich na den örtlichen Verhältnissen, jedoch kann in jedem Falle d Kesselanlage mit oder ohne Vorwärmer betrieben werde

Fig. 5 bis 7.

Schematische Anordnung einer Rauchgasvorwärmer-Anlage der König Friedrich August-Hütte.



Je 4, 6, 8 oder 10 Rohre, dem Fuc querschnitt entsprechend gewäl bilden Elemente, aus denen d Vorwärmer zusammengestellt wi Die Rohre der aufeinander folge den Elemente sind versetzt, so d die Heizgase in innigste Berühru mit den Rohren kommen und d Wärme leicht abgeben. Eine selb tätige Rußschabevorrichtung h die Rohre dauernd von Ruß u Flugasche rein. Das Speisewas wird im Gegenstrom durch d Rohre geleitet. Die Vorwärmer si bereits recht wirtschaftlich, we die Rauchgastemperatur nur rd. 2 beträgt. Das Wasser tritt bei Fig. 7, in den Vorwärmer, fli nach unten und steigt durch d Rohre 1 bis 7 wieder nach ob dann strömt es durch den ober Verbindungskrümmer nach dem zweiten Element und läuft derselben Weise von Element zu Element stets von unt nach oben in entgegengesetzter Richtung zu den Rauchgas Jedes Element hat für sich ein Schlammablaßventil und außerdem mit einem Kugelventil ausgerüstet, damit die et darin enthaltene Luft selbsttätig entweichen kann.

Nach einem amtlichen Bericht über **Unfälle in el trischen Betrieben in den Bergwerken Preußens im Ja 1907**[1]) sind insgesamt 26 Unfälle vorgekommen, von der 13 tödlich verlaufen sind. Die Ursachen sind wieder versch denster Art: eigene mehr oder minder große Fahrlässigk der Verletzten und Unzulänglichkeit der Anlagen und verw deten Geräte. Grundsätzlich wichtig aber ist, daß alle diese lagen unter scharfer amtlicher fachmännischer Ueberwachu stehen. Es zeigt sich hier, wie bei den Beratungen über

[1]) Zeitschrift für das Berg-, Hütten- und Salinenwesen 1908 He S. 503.

DEFENDANT'S EXHIBIT Y. 1513

TRANSLATION OF ARTICLE IN THE "ZEITSCHRIFT DES VEREINES DEUTSCHER INGENIEURE", VOL. 52, NOV. 28, 1908, PP. 1934, 1935

A Kablitz ribbed-tube economizer is shown in Fig. 3.

Cast iron is used for the tube because it resists best the chemical action and because it is the cheapest. A large absorption surface for the heat of the gases is created by ribbing the tube. The heat conductivity coefficient of the gases (K=about 20 kg. cals. per sq. m. per 1 deg. cent. per hour as the greatest value with a velocity of about 33 ft. per sec.) is small and moreover the gases do not reach equally effectively 1514
all parts of the tube. On the other hand the surface for the delivering of the heat to the water may be several times smaller because of the much larger transmission coefficient and the uniform washing over by water (K=about 1000 as the lowest value, see Hutte 1905, part 1, p. 281). The surface in contact with the gas, or the ribbed tube surface, should then be at least 1000 : 20=50 times larger than the surface in contact with the water. The ribbed tube is therefore particularly adapted for this purpose.

In this economizer the water passes through a unit of 14 ribbed tubes of 2 m. (6 ft. 8 in.) length each, 100 mm. internal diameter (3.94 in.), and 4 sq. m. (43 sq. ft.) of exter- 1515
nal ribbed tube surface. Through all these tubes, one after

another, the water flows in the opposite direction to that of the gas in order to have as great a drop of temperature as possible at all points. The whole element has 55 sq. m. (591 sq. ft.) of heat surface reached by the gas.

All 14 ribbed tubes hang screwed by their upper ends to the distributor which at the same time serves as an air tight

"cover-plate", so that no cold air can be sucked into the
1516 economizer. This distributor joins pairs of adjacent tubes by means of 6 large passages while the lower ends are joined by 7 180° bends. In this way free expansion of the ribbed tubes is allowed. At one end of the distributor plate the cold water enters from above, flows through all the ribbed tubes, alternately ascending and descending in them and then emerges, warmed, but always flowing in the opposite direction to that in which the gas flows. The 6 large water passages in the distributor are joined to one another by 5 small passages of suitable diameter to carry off gases and steam.

1517 The fear that the external cleansing would be difficult has proved groundless because with gas-velocities of about 5 m. (16 ft.) per sec. no foreign bodies adhere except the soot which sticks like snowflakes to every surface which offers, but it also is blown away at a velocity of 10 m. (33 ft.) per sec. It is then within our own control to prevent any soot-formation worth mentioning, the more so as a velocity of 10 m. (33 ft.) per sec. corresponds to a draft loss of only about 5 to 7 mm. (.2 to .28 inches) of water because

Kablitz flue-gas water heater, p. 1935 –3

the ribs do not cause turbulence in the gas stream but break
1518 it up into small single streams and thus the desired rapid supply of hot gases and carrying off of cooled ones is attained. In order to be able to clean the ribbed tubes easily, there is a steam blower between every 4 ribbed tubes. This is arranged vertically through 5 passages in the upper distributor box, which close automatically. One element weighing 2200 kg. (4850 lb.) requires a space of only 1600 x 730 mm. (5.25 x 2.39 ft.) in plan, and 2400 mm. (7.87 ft.) deep. Several such elements are placed alongside of each other, connected by pipes with 4 divisions and the gas-stream is

made to cross the pipes several times by the use of sheet metal plates (see Fig. 4) so as to obtain high gas velocity. Thus every element of 55 sq. m. (591 sq. ft.) heating-surface is independent of the neighboring element and may be lifted out after releasing the tube connection and by-passing the flow. If the open space be covered with a sheet 1600 x 730 mm., the other elements may continue to operate. Since the tubes may expand fully and an element be replaced during the noon recess, the economizer is placed directly in the main flue avoiding by-pass channels, dampers, etc. 1519

RICHARD KABLITZ, Riga.

1520

Translation of headings in figures in the article on The Kablitz Ribbed Tube Economizer in Z. V. D. I., Vol. 52, page 1934.

Figure 3.

Rippenrohr-Rauchgasvorwarmer, Bauart Kablitz. (Kablitz Ribbed Tube Economizer.)

Dampfstrahlreiniger. (Steam blower.)

1521

Sft 4 Z
11-15. 2

licht dies in klarer Weise. Ferner wird die der Luft ausgesetzte Oberfläche der Späne und damit auch der Abbrand verringert. Durch die Verringerung des Volumens wird auch die Schmelzdauer und dadurch wiederum der Abbrand vermindert, gleichzeitig damit eine Ersparnis an Heizstoffen, Schmelztiegeln, Arbeitslöhnen usw. und eine größere Leistungsfähigkeit des Ofens erzielt.

Es ist nun nicht gleichgültig, ob man Briketts aus reinen Metallspänen oder aus Spänen einer Legierung einschmilzt; doch haben Versuche, die ich u. a. in einem Oelschmelzofen, Bauart Bueß, Hannover, ausgeführt habe, gezeigt, daß auch Briketts aus Legierungen sehr günstige Schmelzergebnisse aufweisen. Einige Schmelzversuche mit Rotgußspänen ergaben z. B. folgende Zusammensetzung:

a) Späne vor der Schmelzung
Kupfer 83,61, Zinn 11,16, Zink 3,63
b) als Briketts eingesetzt nach der Schmelzung
Kupfer 84,24, Zinn 11,27, Zink 2,13.

Es zeigte sich also nicht allein ein nur geringer Verlust, sondern auch keine nennenswerte Verschiebung der Mischverhältnisse. Beim Einschmelzen von chemisch reinen Kupferspänen erhält man in der Regel einen großen Oxydulgehalt im Kupfer, sie sind daher zum Einschmelzen als lose Späne nicht zu gebrauchen. Brikettiert man sie aber, so wird die Oxydulbildung vermieden, und es steht nichts im Wege, die reinen Kupferbriketts als Blockmaterial zu verwenden. Die Angaben über den Verlust durch Abbrand beim Einschmelzen von losen Metallspänen gehen nach den Mitteilungen namhafter Werke sehr weit auseinander. Je nach der Art der Späne und nach den vorhandenen Schmelzeinrichtungen beträgt er z. B. bei Messingspänen bis zu 20 vH, bei Rotgußspänen bis zu 10 vH. Schmelzversuche mit brikettierten Spänen haben dagegen im ungünstigsten Falle bei Messing und bei Rotguß nur die Hälfte dieses Verlustes gezeigt. Beim Schmelzen von Aluminiumspänen muß man mit Verlusten bis zu 50 vH rechnen, die Brikettierung bringt hier ebenfalls entsprechende Ersparnisse. Natürlich müssen die Metallspäne möglichst rein, d. h. ungemischt mit Spänen andrer Art, brikettiert werden.

Eine Reihe bedeutender Firmen hat seit Jahren die Brikettierung von Metallspänen in großem Umfange durchgeführt. Die Vorteile sind hier erkannt worden, und man zahlt je nach Art und Güte der Späne 25 bis 70 ℳ/t für das Brikettieren.

Kesselhaus-Reorganisation.[1])

Von **Richard Kablitz** in Riga.

Im folgenden wird über die Tätigkeit einer Gesellschaft für Verbilligung der Dampferzeugungskosten berichtet, die sich unter besondern Bedingungen mit der Reorganisation von Kesselanlagen zur Hebung ihrer Wirtschaftlichkeit befaßt. Vorweg sei bemerkt, daß den Berechnungen die bekannte Formel für den Wirkungsgrad $\eta = \frac{D}{B}\frac{W}{K}$ zugrunde gelegt wird, worin D die erzeugte Dampfmenge in kg/st, B die verfeuerte Brennstoffmenge in kg/st, W die in 1 kg Dampf unter Berücksichtigung der Speisewassertemperatur enthaltenen Wärmemenge und K die in 1 kg Kohle enthaltene nutzbare Wärmemenge bedeutet. Aus dieser Formel wird mit Hülfe des Preises für die Wärmeeinheit der Kohlen der jeweilige Dampfpreis (für 1000 kg) berechnet. Sind nun die Kosten der vollständigen Reorganisation bei der Vereinbarung bestimmt, so ist zur Festlegung der Tilgungszeit nur noch die gesamte zu verdampfende Wassermenge oder die zu verbrauchende Kohlenwärmemenge bei sonst gleichen Bedingungen zu ermitteln. Diese berechnen sich mit Hülfe des Unterschiedes des 1000 kg-Dampfpreises vor und nach dem Umbau, der die Ersparnis darstellt, und durch den die Umbaukosten zu decken sind. Wird der ursprüngliche Dampfpreis höher angenommen, so wird der Unterschied kleiner und die zu verheizende Kohlenmenge, somit auch die Tilgungszeit größer, und umgekehrt.

Es kommt daher auf die genaue Bestimmung des ursprünglichen Wirkungsgrades (η) oder des Dampfpreises nicht an, weil sich dadurch nur die Tilgungszeit ändert.

Der Wirkungsgrad bewegt sich um $\eta = 0{,}55$, wenn keine Abgasvorwärmer vorhanden sind, und diese Zahl kann je nach der Kesselhauswartung um etwa 5 vH größer oder kleiner werden. Höhere Werte als 60 vH sind für das Jahresmittel kaum zu erwarten.

Zwei von der Gesellschaft für Verbilligung der Dampferzeugungskosten erfolgreich durchgeführte Kesselhaus-Umbauten sollen das eben Gesagte bekräftigen und die Lebensfähigkeit solcher Gesellschaften dartun.

[1]) Sonderabdrücke dieses Aufsatzes (Fachgebiete: Dampfkessel sowie Fabrikanlagen und Werkstatteinrichtungen) werden an Mitglieder des Vereines und Studierende bezw. Schüler technischer Lehranstalten gegen Voreinsendung von 35 ₰ postfrei abgegeben. Andre Bezieher zahlen den doppelten Preis. Zuschlag für Auslandporto 5 ₰. Lieferung etwa 2 Wochen nach dem Erscheinen der Nummer.

Kesselhaus-Reorganisation eines Panzerplatten-Walzwerkes.

Die Voruntersuchungen hatten einen mittleren Wirkungsgrad von

$$\eta = \frac{D}{B}\frac{W}{K} = 6{,}1 \times \frac{615}{6800} = 0{,}55$$

ergeben. Da der Preis von 1000 kg Kohlen 22,44 ℳ betrug, so errechneten sich die Kosten für 1000 kg des verdampften Wassers zu

$$\frac{22.44}{6{,}1} = 3{,}67 \text{ ℳ}.$$

Nachdem die Umbaukosten, der zu erwartende Wirkungsgrad und die Vorwärmung des Kesselspeisewassers durch Abdampf festgelegt worden waren, konnten die neuen Dampfkosten bestimmt werden. Dann wurden die zu verdampfende Wassermenge und die dazu nötige Anzahl der Kohlen Wärmeeinheiten zur Errechnung der Tilgungszeit bestimmt. Da die Zeit 1½ Jahre nicht überschreiten sollte, so mußte Sorge dafür getragen werden, daß leistungsfähige Vorrichtungen bei geringen Anschaffungskosten und geringen Einbaukosten verwandt wurden. Außerdem mußten die Vorrichtungen bis auf die Handfeuerung möglichst selbsttätig arbeiten, weil der Betrieb Tag und Nacht ging und die Heizer nicht als gut zu bezeichnen waren.

Auf Grund obiger Zahlen wurde ein umfangreicher Vertrag abgeschlossen. Die Gesellschaft hatte alle Reorganisationskosten einschließlich des Einbaues aus ihren Mitteln zu bestreiten und erhielt die Entschädigung lediglich aus der nachgewiesenen Ersparnis.

Beschreibung der Anlage.

Die Kesselanlage bestand aus 16 Zweiflammrohrkesseln von je 90 qm Heizfläche, die in 2 gleiche Gruppen zu 8 Kesseln geteilt waren, s. Fig. 1 bis 3. Zwischen den beiden Gruppen waren die Speisepumpen angeordnet, deren Abdampf in Vorwärmern ausgenutzt wurde. Jede Gruppe arbeitete auf einen Schornstein, zu dem ein gemeinsamer Fuchs führte, in den ein Rauchgasvorwärmer, Bauart Kablitz, gehängt wurde, da ein andrer Raum dafür nicht vorhanden war.

Von der Feuerungskontroll-Gesellschaft wurden geliefert:

1) 32 Sekundärluft-Automaten, Fig. 4 bis 6, die an den Feuertüren angebracht, Luft über den Rost führen, dadurch die sich nach dem Beschicken entwickelnden Kohlenwasserstoffe verbrennen und die lästige schwarze

Fig. 1 bis 3.

Aufstellung eines Rippenrohr-Rauchgasvorwärmers, Patent Kablitz, in 2 Gruppen von insgesamt $2 \times 6 \times 70 = 840$ qm Heizfläche in einem Panzerplattenwalzwerk.

Maßstab 1 : 300.

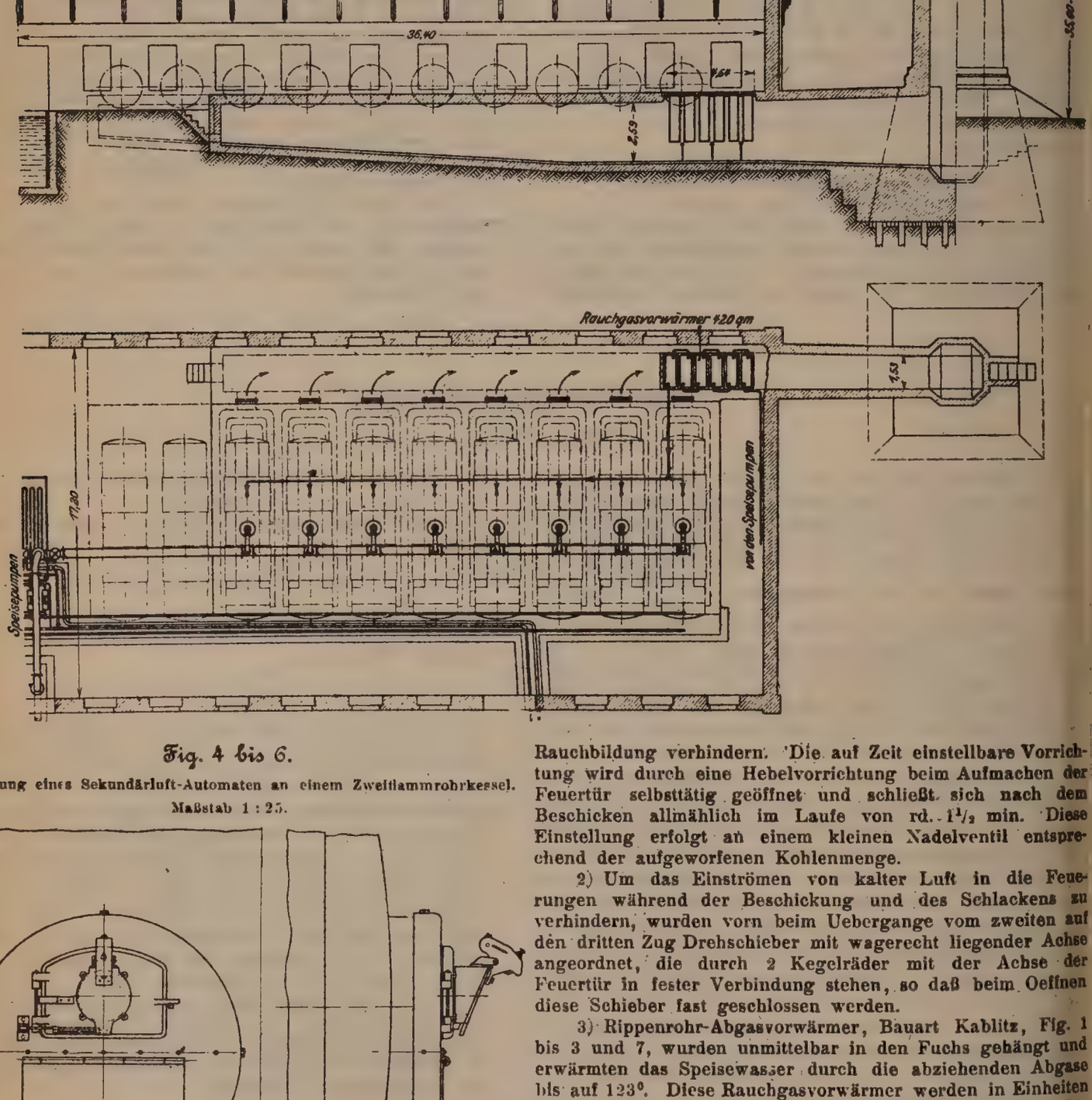
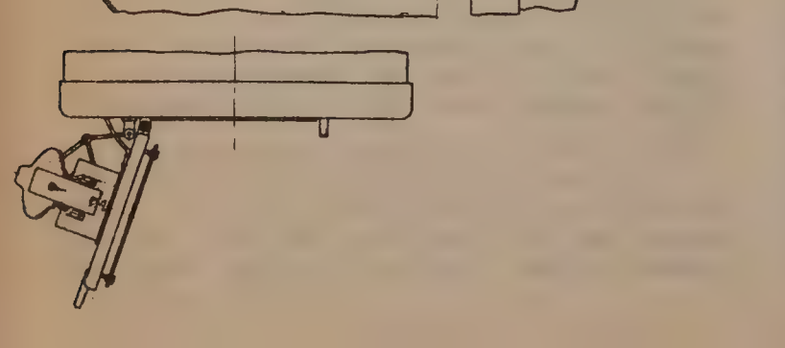


Fig. 4 bis 6.

Anordnung eines Sekundärluft-Automaten an einem Zweiflammrohrkessel.

Maßstab 1 : 25.



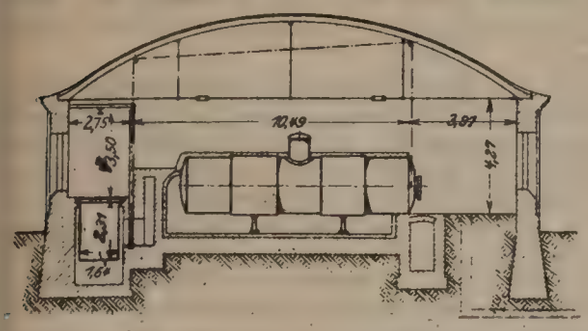
Rauchbildung verhindern. Die auf Zeit einstellbare Vorrichtung wird durch eine Hebelvorrichtung beim Aufmachen der Feuertür selbsttätig geöffnet und schließt sich nach dem Beschicken allmählich im Laufe von rd. $1^1/_2$ min. Diese Einstellung erfolgt an einem kleinen Nadelventil entsprechend der aufgeworfenen Kohlenmenge.

2) Um das Einströmen von kalter Luft in die Feuerungen während der Beschickung und des Schlackens zu verhindern, wurden vorn beim Uebergange vom zweiten auf den dritten Zug Drehschieber mit wagerecht liegender Achse angeordnet, die durch 2 Kegelräder mit der Achse der Feuertür in fester Verbindung stehen, so daß beim Oeffnen diese Schieber fast geschlossen werden.

3) Rippenrohr-Abgasvorwärmer, Bauart Kablitz, Fig. 1 bis 3 und 7, wurden unmittelbar in den Fuchs gehängt und erwärmten das Speisewasser durch die abziehenden Abgase bis auf 123°. Diese Rauchgasvorwärmer werden in Einheiten von 70, 90, 110 und 132 qm Heizfläche hergestellt. Für das Walzwerk wurden für jede Gruppe 6 Einheiten von je 70 qm gewählt, weil diese den Gasgeschwindigkeiten, Kanalabmessungen und andern Umständen am meisten entsprachen. Jede Einheit besteht in der Hauptsache aus drei Teilen: dem oberen Verteilkörper, den darangeschraubten Rippenrohren und den je 2 Rippenrohre verbindenden unteren Krümmern. Das Wasser tritt in den ersten Verteilkörper ein, strömt auf- und absteigend der Reihe nach durch alle Rohre und tritt am andern Ende warm aus, um in die nächste Einheit zu gelangen. Zum Reinigen dient eine Dampf-Abblasevorrichtung, die aus einem fahrbaren eisernen Rahmen mit beweglichen Dampfzuleitungsrohren besteht, welche zwischen die Rippenrohre hinabgelassen werden, s. Fig. 8. Der Dampf von rd. 4 at strömt durch kleine Oeffnungen aus und befreit die Rippenrohre von Asche und

Ruß. Das Abblasen, das bei 70 qm Heizfläche rd. 1 min dauert, wird alle sechs Stunden vorgenommen.

Für diese Abgasvorwärmung sprachen der sehr billige Preis sowie die gute Ausnutzung der Wärme infolge der engen und geschlossenen Bauart und das Hineinhängen in

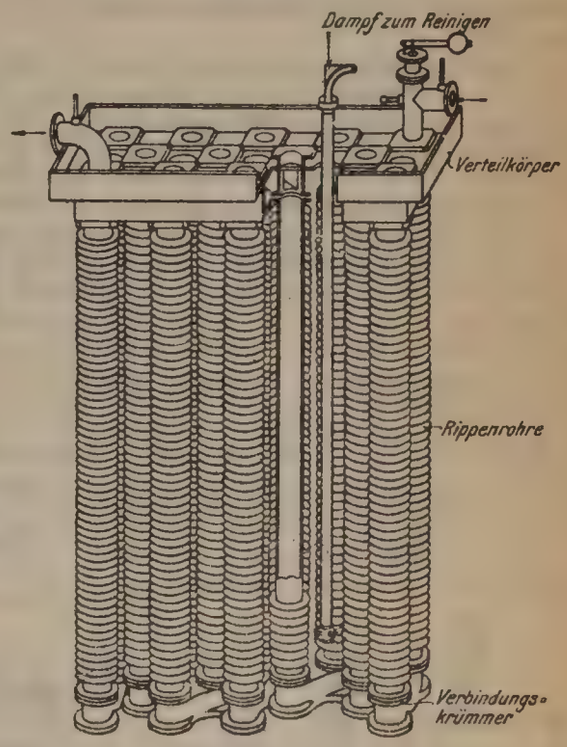


den Fuchs selbst. Auch kam eine möglichst billige und einfache Einmauerung und eine schnelle Aufstellung in Frage. Da kein Gas-Umlaufkanal vorhanden war, so mußte völlige Betriebsicherheit gewährleistet sein; dem kam die Möglichkeit der freien Ausdehnung durch das Aufhängen des Vorwärmers wie auch die Möglichkeit, jederzeit eine Einheit über Mittag herausheben und mit den andern Einheiten ungestört weiterarbeiten zu können, sehr zu statten. Diese Vorsicht erwies sich jedoch als unnütz bis auf die Reinigung von Kesselstein, wozu man den Vorwärmer heraushebt und mit dem elektrisch angetriebenen Fräser, Fig. 9, von einer sehr harten Schicht bis zu 10 mm Dicke verhältnismäßig rasch befreit. Das Speisewasser wurde im Mittel von 50° auf 123° vorgewärmt (s. Diagramm Fig. 15), wobei die Gase von 300° auf rd. 140° abgekühlt wurden.

Die Wärmeübertragung betrug $k = 9$, bezogen auf 1 st, 1 qm und 1° Temperaturunterschied, erreichte aber bei

Fig. 7.

Rippenrohr-Abgasvorwärmer, Bauart Kablitz.



Differenzzugmesser bestimmt und betrug im Mittel 4 bis 5 m Wassersäule.

4) Die Abdampfvorwärmer zum Ausnutzen des Auspu dampfes der Walzenzugmaschinen und Pumpen, Fig. 10 1 12, haben vom Dampf umspülte glatte Messingrohre, dur

Fig. 8.

Vorrichtung zum Reinigen des Abgasvorwärmers.

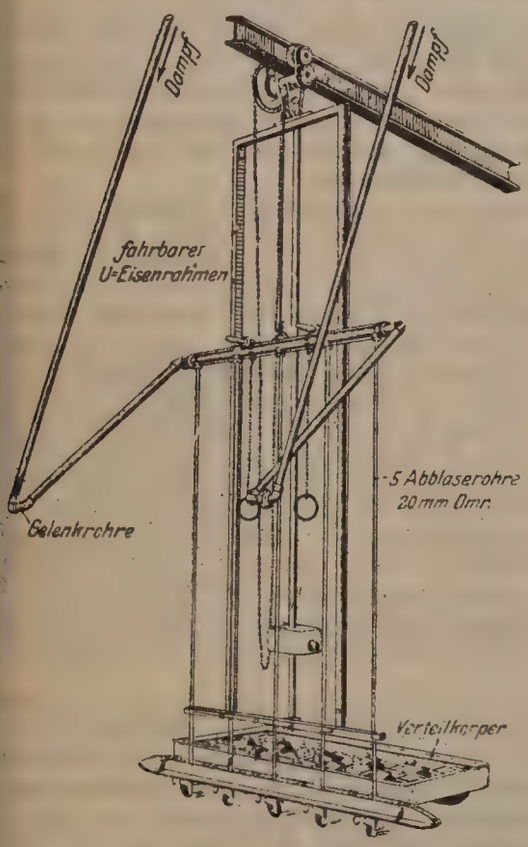


Fig. 9.

Elektrisch betriebener Fräser zum Reinigen der Rauchgas-Vorwärmerrohre.

Maßstab 1 : 25

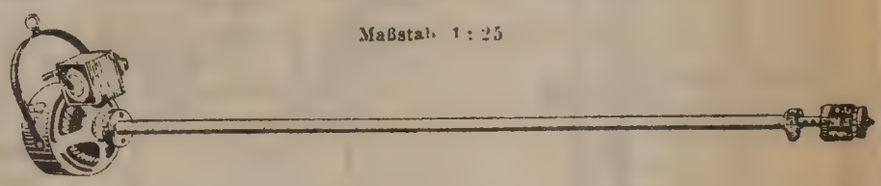
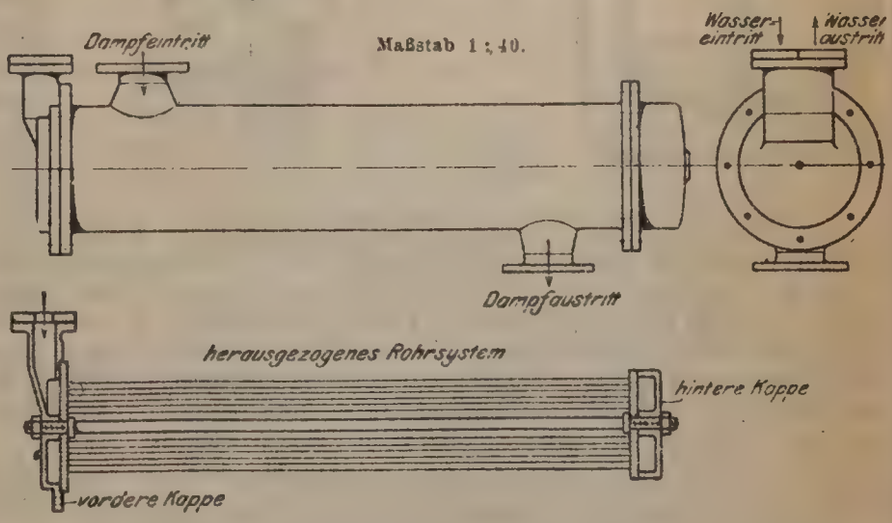


Fig. 10 bis 12. Abdampfvorwärmer.



kurzen Versuchen und starken Belastungen bisweilen auch $k = 12$. Hieraus allein ist schon ersichtlich, daß diese Zahl stark von der Menge der dem Vorwärmer zugeführten Gase abhängt.

Der Zugverlust im Rauchgasvorwärmer wurde durch

die das Wasser fließt. Jede Maschine erhielt ihren eigen Vorwärmer, da sie abwechselnd arbeiten, und alle Pump einen gemeinsamen. Alle Abdampfvorwärmer sind hint einander geschaltet, um möglichst beständig warmes Was zu erhalten. Ein eingeschalteter Thermophor sorgt daf daß die Pumpen nicht auch kaltes Wasser in die beiden g ßen Behälter schaffen, indem er die betreffende Pum selbsttätig ausschaltet. Aus den beiden Behältern entnehm

lie Speisepumpen das Wasser von rd. 40°, das dann im Pumpen-Abdampfvorwärmer auf rd. 50° und im Rauchgasvorwärmer weiter auf die Speisewassertemperatur von 123° erwärmt wird.

5) Kolbenwassermesser der Bauart Kennedy-Eckardt, Fig. 13, die zwar etwas teuer, aber zuverlässig arbeiten. Sie wurden während der Kontrolle mehreremal geeicht. Die Fehler überstiegen nie ± 1½ vH. Diese Wassermesser erscheinen auf den ersten Blick etwas verwickelt, sind sie jedoch einmal richtig eingebaut, so arbeiten sie durchaus zuverlässig.

Die Wirkungsweise des Wassermessers ist folgende: Im Zylinder geht ein Kolben lose auf und ab. Die Abdichtung wird durch Kolbenringe erzielt. Das Wasser tritt abwechselnd bald unter, bald über den Kolben und wird durch einen Corliss-Hahn gesteuert. Dieser Hahn wird durch eine mit der Kolbenstange verbundene Zahnstange und ein Schlaggewicht betätigt. Die Hubbewegung der Zahnstange wird gleichzeitig auf das Zählwerk übertragen. Das Zählwerk addiert nicht die Anzahl der Hübe, sondern die Hubwege. Die durchgeflossene Wassermenge wird unmittelbar

Fig. 13.

Kolbenwassermesser, Bauart Kennedy-Eckardt.

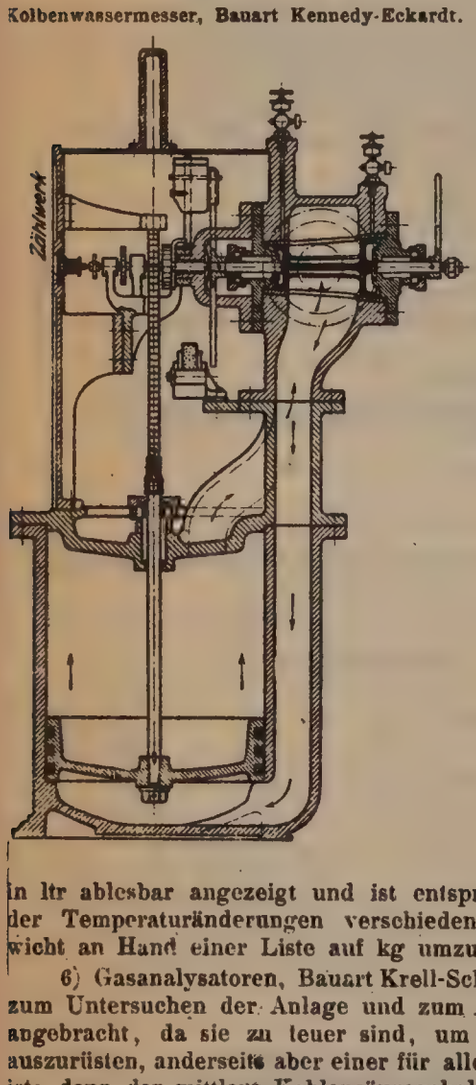
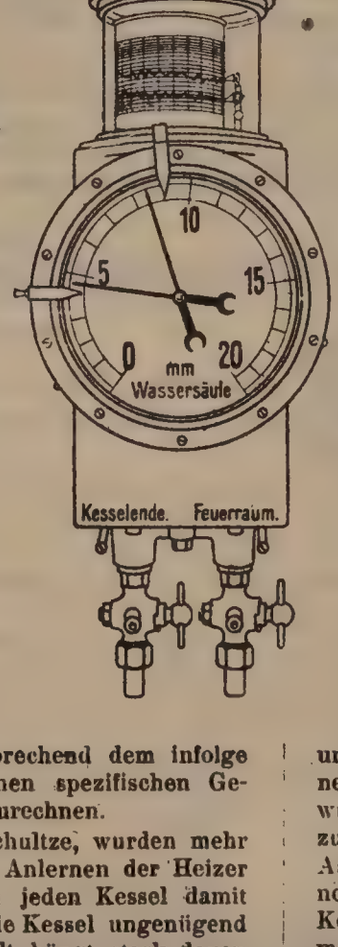


Fig. 14.

Verbund-Zugmesser von Schultze-Dosch.



in ltr ablesbar angezeigt und ist entsprechend dem infolge der Temperaturänderungen verschiedenen spezifischen Gewicht an Hand einer Liste auf kg umzurechnen.

6) Gasanalysatoren, Bauart Krell-Schultze, wurden mehr zum Untersuchen der Anlage und zum Anlernen der Heizer angebracht, da sie zu teuer sind, um jeden Kessel damit auszurüsten, anderseits aber einer für alle Kessel ungenügend ist; denn der mittlere Kohlensäuregehalt hängt stark davon ab, wie viel Kessel still liegen, da durch die meist ungenügend schließenden Schieber kalte Luft angesaugt wird. Daher erhielt jeder Kessel einen Verbundzugmesser.

7) Die Verbundzugmesser von Schultze-Dosch, Fig. 14, gestatten die Beurteilung des Luftüberschusses durch Anzeige des Zuges über dem Rost und des Zugunterschiedes zwischen dem Kesselende und dem Feuerraum, während der Gasanalysator dieselbe Aufgabe durch Anzeige des Kohlensäuregehaltes erfüllt. Sie haben zwei verschiedenfarbige Zeiger, die sich voneinander unabhängig bewegen können. Für einen bestimmten Kessel muß der Winkel zwischen den beiden Zeigern gleich bleiben, auch wenn die Belastung wechselt. Der günstigste Winkel wird durch einen Gasanalysator bestimmt, und die äußeren Zeiger werden danach eingestellt. Die Aufgabe des Heizers ist es, diesen Winkel einzuhalten, wobei beide Zeiger je nach Belastung steigen oder sinken können und die aufgezeichneten Linien im Diagramm nebeneinander laufen.

8) Schließlich erhielt die Anlage Pyrometer zum Messen der Abgastemperaturen und Thermometer für die Wassertemperaturen.

Laut Vertrag waren folgende Hauptpunkte einzuhalten:

Die Gesellschaft hat die erwähnten Einrichtungen kostenlos zu liefern, aufzustellen, in Gang zu setzen, die Heizer anzulernen und den Betrieb laufend zu prüfen. Der Einheitspreis für Kohlenwärme ist für alle Berechnungen als gleichbleibend zu betrachten. Zur Analyse wird täglich unmittelbar vom Eisenbahnwagen eine mittlere Probe von rd. 40 kg entnommen und 3 Tage im Kesselhause zur Bestimmung der Lagerfeuchtigkeit getrocknet. Im Laboratorium werden die in einer Woche gesammelten Proben auf den Gehalt an chemisch gebundenem Wasser und Asche untersucht und dann zur Ermittlung des Wärmewertes in der Kröckerschen Bombe verbrannt. Aus diesem wird der nutzbare Wärmewert der lufttrocknen Kohle bestimmt und als Grundlage für die Beurteilung der Kohle und für die weitere Berechnung angenommen. Die Dampffeuchtigkeit vermindert den Wärmewert von 1 kg Dampf um 10 WE. Die Kessel werden in den früheren Zeitabständen gereinigt. Die gewöhnlichen Ausbesserungen, wie Erneuerung der Roste, Isolationen, Pumpen usw., gehen auf Kosten des Walzwerkes.

Zum Nachweis der Ersparnis führte das Walzwerk unter Aufsicht eines Fachmannes der Gesellschaft ein vollständiges Kesselhausbuch, in das alle Ergebnisse eingetragen wurden, um den Wirkungsgrad und den Dampfpreis sicher festzustellen. Die Kohlen wurden gleichzeitig im Laboratorium des Werkes und im Rigaschen Polytechnikum untersucht, und die Analysen stimmten überein, weil das gleiche Verfahren angewandt wurde.

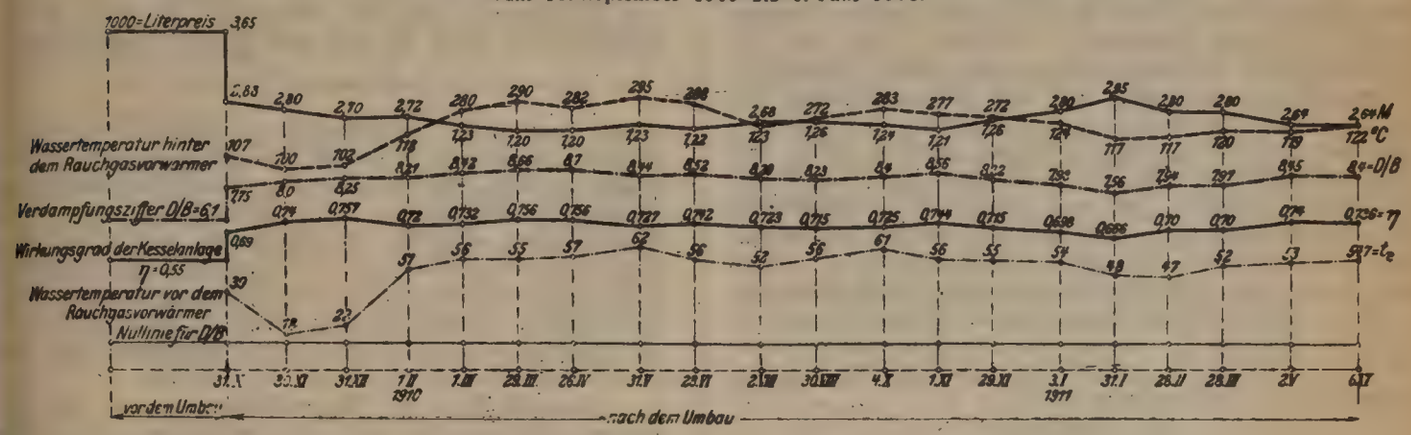
Die Garantiefrist für fehlerfreies, gutes Material und zweckmäßige Ausführung erstreckte sich auf zwei Jahre nach Ablauf der Prüfzeit, ferner war eine geringste Ersparnis während der Prüfzeit gewährleistet, bei deren Unterschreitung das Walzwerk das Recht hatte, die Zahlung einzustellen. Das Gleiche galt für zweifelhafte Prüfergebnisse.

Nachdem alle Vorrichtungen eingebaut und das Kesselhaus im allgemeinen in Ordnung gebracht war, begann die Prüfung, die rd. 1½ Jahre währte und von beiden Teilen gleichzeitig ausgeübt wurde. Sie bestand in der Hauptsache in folgendem: Alle halbe Stunden wurden an den Wassermessern die verdampfte Wassermenge abgelesen, ferner wurden die Wassertemperaturen vor den Vorwärmern, vor und hinter den Rauchgasvorwärmern, sowie die Abgastemperaturen gemessen und Anzahl und Betriebstunden der arbeitenden Kessel nebst dem Dampfdruck aufgeschrieben. Die Kohlenmenge wurde wagenweise auf einer Wage bestimmt und die Proben zur Untersuchung entnommen. Auch die zurückbleibende Asche und Schlacke wurde gewogen. Endlich wurden noch der Zug über dem Rost und der Zugunterschied im Kessel, am Rauchgasvorwärmer und am Schornsteinfuß gemessen; sie betrugen im Mittel 3, 6, 16 und 21 mm Wassersäule.

Auf Grund dieser Unterlagen wurden dann monatlich Abrechnungen über die gesamte verdampfte Wassermenge wie auch die verbrannte Kohlenmenge unter Berücksichtigung des früheren Heizwertes aufgestellt. Hieraus ergab sich die Verdampfung und nach Ermittlung der mittleren Wassertemperaturen die von 1 kg Dampf aus der Kohle aufgenommene Wärmemenge (W). Unter Berücksichtigung des täglich bestimmten Feuchtigkeitsgehaltes der Kohle wurde der mittlere Heizwert und dann der Wirkungsgrad der Kesselanlage gefunden. Schließlich wurde noch der Preis von 1000 kg verdampften Wassers und aus der Monatswassermenge die gesamte Ersparnis berechnet. Die Heizer-

Fig. 15.

Diagramm der Arbeit der Kesselanlage eines Panzerplatten-Walzwerkes vor dem Umbau und während der Kontrollzeit vom 10. September 1909 bis 6. Juni 1911.



ämien wurden in festen Sätzen nach dem Wirkungsad der Anlage steigend gezahlt, wobei die fällige Summe eist nach den Arbeitstunden verteilt wurde; jedoch erhielen auch öfters bessere Heizer auf Kosten der schlechteren ich Angaben des sie anlernenden Beamten der Gesellschaft ehr.

Die Ergebnisse des Umbaues waren, wie aus Fig. 15 ichtlich, recht günstig:

ie mittlere Vorwärmung durch die Vorwärmer betrug $50^0 - 15^0 = 35^0$,

e mittlere Vorwärmung durch die Rauchgasvorwärmer betrug $123^0 - 50^0 = 73^0$,

er Wirkungsgrad stieg von $\eta = 0{,}55$ im Mittel auf 0,724, und die Verdampfung, auf denselben nutzbaren Heizwert der Kohlen (6800 WE/kg) umgerechnet, war dann im Mittel $\frac{D}{B} = 8{,}25$.

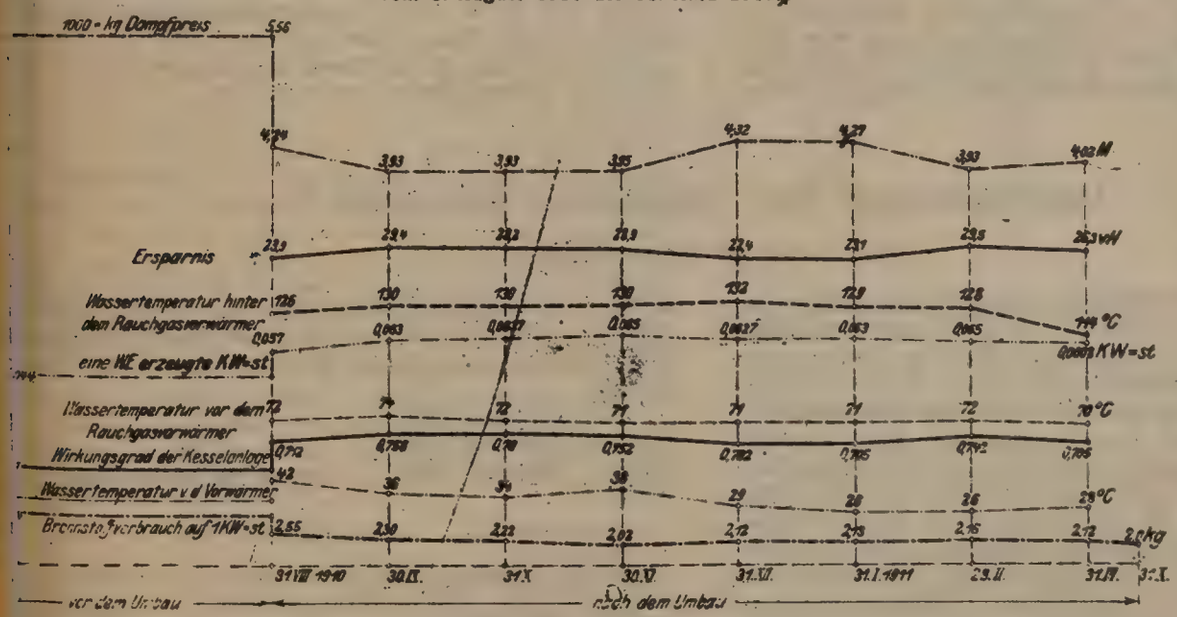
Zur weiteren Erläuterung dienen die folgenden kurzen Angaben über den Umbau eines städtischen Elektrizitätswerkes. Aufgestellt wurden fast dieselben Vorrichtungen wie vorher, und auch der Vertrag war dem ersten ähnlich. Das Speisewasser, das bis dahin mit einer Temperatur von rd. 32° in die Kessel gepumpt war, wurde durch Vakuum- und Auspuff-Abdampfvorwärmer bis auf 72° im Mittel vorgewärmt und gelangte weiter zum Rauchgasvorwärmer, von wo es mit 127° im Mittel in die Kessel gespeist wurde. Der Wirkungsgrad der Kesselanlage, der vor dem Umbau 57 vH betrug, stieg auf 73 vH im Mittel. Der Preis für 1000 kg Dampf, der vor der Umgestaltung 5,56 ℳ betrug, belief sich nachher auf 4,07 ℳ, so daß sich 26,8 vH Ersparnis ergeben. Davon entfielen auf die Verbesserung des Wirkungsgrades 22 vH, der Rest auf die Abdampfverwertung. Zur Erzeugung von 1 KW-st waren früher 2,84 kg Brennstoff erforderlich, später nur 2,23 kg. Zieht man den Heizwert in Betracht, so erzeugte 1 WE des Brennstoffes vor dem Umbau 0,0461 KW-st, nach dem Umbau 0,0621 KW-st im Mittel, was einer durchschnittlichen Ersparnis von

$$\frac{0{,}0621 - 0{,}0461}{0{,}0621} = 0{,}26 = 26 \text{ vH}$$

entspricht. Die wichtigsten Zahlen der monatlichen Protokolle sind in Fig. 16 wiedergegeben.

Fig. 16.

Diagramm der Arbeit der Kesselanlage eines elektrischen Kraftwerkes vor dem Umbau und während der Kontrollzeit vom 1. August 1910 bis 31. März 1911.



Wie aus vorstehendem ersichtlich, läßt sich durch Anwendung zweckmäßiger Maschinen und Geräte, durch Einführung einer genauen und vollständigen Dauerprüfung nicht nur Betriebsicherheit und Rauchverhütung, sondern auch eine bedeutende Ersparnis bei einer klaren Uebersicht über die ganze Kesselhausarbeit erzielen. Auch läßt sich u. a. durch die Kesselhauskontrolle feststellen, welche Kessel und Dampfmaschinen am günstigsten arbeiten, welche vorhandenen Fehler zu verbessern sind, welcher Brennstoff am vorteilhaftesten ist und wie man ihn einkaufen muß.

Bei dieser Gelegenheit möchte ich einiges über die Kohlenanalyse und ihre Wichtigkeit beim Ankauf der Kohle sagen. Wenn ein Werk eine gewisse Kohlensorte bezieht,

Preis von 1000 kg Dampf stellte sich somit im Mittel auf $22{,}14 : 8{,}25 = 2{,}72$ ℳ.

Ersparnis betrug demnach $\frac{3{,}67 - 2{,}72}{3{,}67} = 0{,}26 = 26$ vH und stellte sich aus folgenden Einzelwerten zusammen:

wärmer	5,9 vH
chgasvorwärmer	12,3 »
undärluft-Automaten, Ueberwachung usw. als Restglied	7,8 »
zusammen	26,0 vH

Die Garantie wurde wesentlich überschritten. Die atlich erwiesene Ersparnis betrug über 6500 ℳ.

die von einem bestimmten Schacht herrührt, so ist es genügend, nur eine vollständige Analyse zu machen, durch die der chemisch gebundene Wassergehalt, die Asche, der kalorimetrische Heizwert und der Wasserstoff bestimmt werden. Um den nutzbaren Heizwert zu ermitteln, muß man die Lagerfeuchtigkeit bestimmen, indem eine Probe unmittelbar aus dem Haufen oder besser aus dem Wagen während des Wägens entnommen, einige Tage getrocknet und das Gewicht des dabei verdunsteten Wassers ermittelt wird. Da dieser Feuchtigkeitsgehalt sehr oft wechselt, so muß er täglich ermittelt werden. Ist nun einmal eine vollständige Analyse einer Kohlensorte vorhanden, so genügt zur Bestimmung des Heizwertes einer andern Menge Kohle aus demselben Schacht die einfache Feststellung des Aschengehaltes, wie sie in jedem kleinen Laboratorium vorgenommen wird. Bezeichnet man mit K_e und K_{e1} den kalorimetrischen Heizwert der ersten und der zweiten Probe und mit a und a_1 den entsprechenden Aschengehalt, so ist

$$K_{e1} = \frac{K_e(1 - a_1)}{1 - a},$$

wobei K_e und a durch die erste Analyse bestimmt wurden.

Beim Einkauf sollte die Kohle stets nach dem Heizwert beurteilt werden; denn im Grunde kommt es doch auf die in 1 kg enthaltene Wärmemenge und auf den Preis hierfür an. Es sollten daher stets Analysen der betreffenden Kohlensorten in der vorgezeichneten verbilligten Weise durchgeführt werden. Selbstverständlich sind die sonstigen Eigenschaften der Kohle, wie Art der Schlackenbildung, Stückgröße, übermäßiger Aschen- und Schwefelgehalt, Lagerungsmöglichkeit, flüchtige Bestandteile usw., mit zu berücksichtigen. Demnach darf wohl der Preis der Wärmeeinheit, aber nicht die gekaufte Anzahl der Wärmeinheiten schwanken. Es empfiehlt sich daher, die Kohlen nach Wärmeinheiten und nicht nach Kilogrammen zu kaufen.

Es empfiehlt sich, den vollständigen Umbau von Kesselanlagen auf folgenden Grundlagen vorzunehmen. Bei der Umwandlung der Kohlenwärme in Dampfwärme lassen sich erfolgreich nur zwei Verluste bekämpfen:

Erstens der Verlust durch unverbrannte Kohlenwasserstoffe und Ruß, der durch selbsttätige Feuerungen, oder falls solche zu teuer sind, durch Handfeuerungen mit selbsttätig geregelter Primär- und Sekundär-Druckluft verringert werden muß. Selbsttätige Dauerprüfgeräte zur Bestimmung der unvollkommenen Verbrennung gibt es nicht.

Der zweite Verlust ist der Abgasverlust als Funktion der Temperatur und der Gasmenge. Er wird in vH des Kohlenwertes durch die bekannte Formel ausgedrückt:

$$V = 0{,}66\,\frac{T - t}{CO_2}\,vH,$$

wobei T und t die Temperaturen der Abgase und der Kesselhausluft bezeichnen, während der Kohlensäuregehalt die Gasmenge vertritt. Zur Verringerung dieses Verlustes empfiehlt es sich in erster Linie, die Abgastemperatur durch Rauchgasvorwärmer möglichst zu verringern, weil das Verfahren unabhängig vom Heizer ist, und weil dann die Verringerung des Luftüberschusses oder der Gasmenge keine weiteren wesentlichen Vorteile bringt. Obgleich es brauchbare Gasanalysatoren zur Anzeige des Luftüberschusses gibt, nützen sie doch nur bei gutem Willen des Heizers.

Demnach bleibt von Dauer-Meßgeräten nur der Wassermesser, weil er nicht nur zur Bestimmung des 1000 kg Dampfpreises nötig ist, sondern auch angibt, wieviel Dampf das Kesselhaus geliefert hat. Einige Rauchgas-Analysatoren oder Ersatzgeräte sind sehr erwünscht, um die Feuerung auf die günstigste Arbeitsweise einzustellen, während Dauermessungen höchstens noch die billigen Verbund-Zugmesser in Frage kommen.

Zusammenfassung.

Hinweis auf die Wichtigkeit und Durchführbarkeit von Kesselhaus-Reorganisationen. Beschreibung der zweckmäßigen Umgestaltung zweier Kesselanlagen. Angabe der erreichten Vorteile und Ersparnisse.

Ergebnisse der Voruntersuchungen, Feststellung der Kosten und Verpflichtungen; kurze Beschreibung der Kesselanlagen und der aufgestellten Geräte: Sekundärluft-Automat, Rippenrohr-Rauchgasvorwärmer, Abdampfvorwärmer, Wassermesser, Gasanalysatoren, Verbund-Zugmesser usw. Angaben über den erzielten Wirkungsgrad der Anlage, über 1000 kg Dampfpreis und die gewonnene Ersparnis.

Es wird empfohlen, den Umbau von Kesselanlagen durch besondere hierfür zu gründende Gesellschaften durchführen und durch diese Dauerprüfungen anstellen zu lassen, wobei die Kosten des Umbaues durch die Ersparnisse gedeckt werden, die während der entsprechend lang bemessenen Dauerprüfung erzielt werden.

Untersuchungen über magnetische Hysteresis.[1]

Von Dr.-Ing. F. Holm in Berlin.

Für die mit Magnetisierungsvorgängen verbundene Erscheinung der Hysteresis bietet noch immer die Webersche Molekulartheorie die einleuchtendste Erklärung. Weber verbindet mit der Magnetisierung von Eisen die Vorstellung, daß dessen von Natur magnetische, aber wirr durcheinander liegende Moleküle durch die magnetisierende Kraft gerichtet werden. Unter der weiteren Annahme, daß bei dieser Umlagerung zwischen den einzelnen Molekülen Reibungskräfte auftreten, ergibt sich als notwendige Folge die Hysteresis, das Nachhinken der magnetischen Sättigung hinter der Feldstärke bei Aenderungen des magnetischen Zustandes und eine der Reibungsarbeit entsprechende Energievergeudung, Fig. 1. Bald nach der Beobachtung dieser Erscheinung wurde auch nachgewiesen, daß bei der graphischen Darstellung eines magnetischen Kreisprozesses (Sättigung B als Funktion der Feldstärke $\mathfrak{H}$) der Flächeninhalt der Hysteresisschleife ein Maß für die Ummagnetisierungsarbeit, die durch Reibung vergeudete Energie, darstellt.

Sämtliche Versuche, einen genauen mathematischen Zusammenhang zwischen der Hysteresisarbeit und der Sättigung zu finden, sind ebenso gescheitert wie das Suchen nach einer mathematischen Beziehung zwischen magnetischer Sättigung und magnetisierender Kraft. Die vielen empirischen Formeln gelten sämtlich nur mit Einschränkungen; die größte praktische Bedeutung haben die Steinmetzschen Gesetze erlangt.

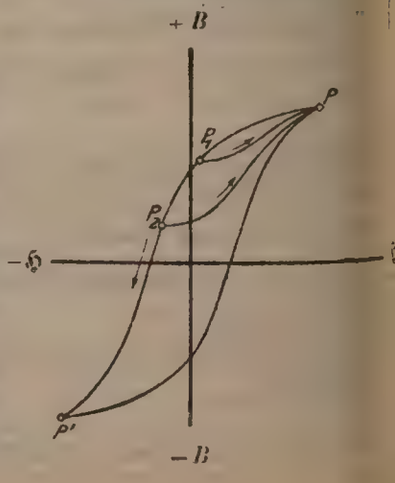
Zuerst hat Steinmetz auf Grund umfangreicher Versuche das Gesetz[2])

$$a_{h\,Erg} = \eta\, B_{max}^{1,6}$$

aufgestellt, welches aussagt, daß bei einem vollen magnetischen Kreisprozeß zwischen den Sättigungsgrenzen $+B_{max}$ und $-B_{max}$ die Hysteresisarbeit für 1 ccm Eisen der 1,6ten Potenz der größten Sättigung proportional ist. Bald darauf erweiterte derselbe Forscher sein erstes Gesetz durch ein

Fig. 1.

Magnetische Kreisprozesse.



[1]) Der ausführliche Versuchsbericht wird in den Mitteilungen über Forschungsarbeiten veröffentlicht werden.

[2]) ETZ 1892 S. 136.

eites — für beliebige Kreisprozesse gültiges — Gesetz[1])

$$a_h \mathrm{Erg} = \eta \left(\frac{\Delta B}{2}\right)^{1,6}$$

hdem er — ebenfalls auf Grund vieler Versuche — gestellt zu haben glaubte, daß der Ummagnetisierungslust gar nicht von dem absoluten Wert der Sättigung, ıdern nur von dem Unterschied der Grenzwerte der magıischen Induktion ($\Delta B = B_1 - B_2$) abhänge.

Da die erste Steinmetzsche Formel das weite Gebiet r Magnetisierungen durch den gewöhnlichen Wechselstrom faßt, hat sie von Anfang an ein ihrem praktischen Wert sprechendes Interesse gefunden und ist auch häufig nach ı verschiedensten Richtungen hin mit gut übereinstimmenı Ergebnissen nachgeprüft worden. Das zweite allgeinere Steinmetzsche Gesetz dagegen — so beachtenswert h für den Theoretiker die überraschend einfache Behung war — hatte zunächst nur geringe praktische Beıtung.

Jedoch mehren sich in neuerer Zeit die Fälle, wo das en nicht von reinen Gleich- oder Wechselströmen magisiert, sondern gleichzeitig mehreren induzierenden Einssen unterworfen wird. Hierher gehört z. B. die gleichtige Induktion durch Gleich- und Wechselstrom oder überıpt durch Ströme verschiedener Frequenz; ferner die Inktion des im Wechselfeld umlaufenden Ankers eines echselstrommotors, die Induktion durch Ströme, deren ıwingungen aus Grund- und Oberschwingungen zusammensetzt sind, usw.

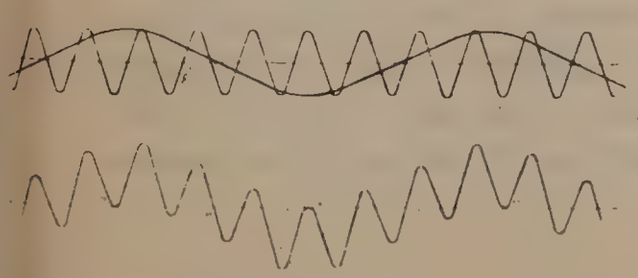
Die magnetischen Vorgänge im Läufer eines Wechselom-Reihenmotors sollen hier als praktisches Beispiel näher rachtet werden. Das von der Ständerwicklung erzeugte tstehende Wechselfeld kann man — wie es Ferraris für Theorie des Einphasen-Induktionsmotors vorgeschlagen — in zwei unveränderliche Drehfelder zerlegen, deren es einzeln halb so stark ist wie das Wechselfeld im Augenck seines Höchstwertes, und die beide — einander entgen — synchron mit dem erregenden Wechselstrom umıfen. Da nun — wenn vielleicht auch nicht mit absoluter nauigkeit, so doch sicher in größter Annäherung — die rhältnisse für drehende und für Wechselstrommagnetisieıg gleich sind, so ergeben beide Drehfelder zusammen die rkung des Wechselfeldes.

Bei völlig synchronem Lauf des Motors bewegt sich der ufer synchron mit dem einen Felde, das im gleichen Sinn läuft. Dieses bedingt für jedes Eisenteilchen einen unveränderlichen magnetischen Zustand, eine »Grundsättigung«, e eine Gleichstrominduktion. Das zweite Drehfeld lagert h derartig über das erste, daß das Eisen um diese Grundtigung herum magnetische Schwingungen erfährt. Das gebnis sind für jeden Teil des Läufereisens »unsymmesche« magnetische Kreisprozesse zwischen zwei Grenztigungen B_1 und B_2, wie sie Steinmetz bei der Aufstellung nes zweiten Gesetzes im Auge gehabt hat.

Sobald der Motor — wie in den meisten Fällen — nicht nchron läuft, hat die »Grundsättigung« keinen festen ert mehr, vielmehr wird der Läufer dann auch durch das te Drehfeld zyklischen Magnetisierungsprozessen — und ar mit der Frequenz der Schlüpfung — unterworfen. 2 zeigt für einen solchen Fall schematisch die Ueber-

Fig. 2.

Zeitlicher Verlauf der Induktion im Läufereisen eines Wechselstrom-Reihenmotors.



[1]) ETZ 1892 S. 519.

einanderlagerung der beiden Felder. Die Schwingungen ergeben zyklische Prozesse gleichen Sättigungsintervalles bei verschiedener absoluter Sättigung.

Es braucht kaum betont zu werden, daß in diesen und ähnlichen Fällen die Kenntnis der Hysteresisverluste von großer Bedeutung und z. B. die Vorbedingung für eine Vorausberechnung des Wirkungsgrades ist.

Bei der Verwendung des zweiten Steinmetzschen Gesetzes fand man jedoch nicht die gleiche befriedigende Uebereinstimmung zwischen der theoretischen Rechnung und den praktischen Ergebnissen wie bei den symmetrischen Magnetisierungszyklen, die das erste Gesetz umfaßt. Diese auch vom Verfasser gelegentlich festgestellten Abweichungen[1]) boten den Anlaß, die Hysteresiserscheinung — mit besonderer Berücksichtigung der bei unsymmetrischen Zyklen auftretenden Verluste — planmäßig zu untersuchen.

Als Versuchstoff wurde ein Paket von gestanzten, einseitig mit Papier beklebten Blechringen benutzt, die im Mittel 0,5 mm stark waren und einen äußeren Durchmesser von 420 mm, einen Innendurchmesser von 399,8 mm hatten. Die verwandten 99 Bleche hatten also einen Eisenquerschnitt von fast genau 5 qcm. Die nach Bedarf über den Ring gelegten Wicklungen wurden immer gleichmäßig über den ganzen Umfang verteilt.

Die von Steinmetz benutzten Meßverfahren — mit Wechselstrom oder mit dem Magnetometer — erschienen für den vorliegenden Zweck zu ungenau. Es wurde für die Hauptversuche mit befriedigendem Erfolg ein von Evershed und Vignoles vorgeschlagenes und von Heinke im Handbuch der Elektrotechnik Band II empfohlenes ballistisches Verfahren benutzt, das für den besondern Fall noch entsprechend vervollkommnet wurde.

Die ballistisch aufgenommenen

symmetrischen Magnetisierungszyklen

nach Fig. 3 lassen die allgemeinen magnetischen Eigenschaften des Versuchseisens erkennen. Die Zahlentafel 1 gestattet eine Prüfung des ersten Steinmetzschen Satzes.

Zahlentafel 1.

B_{max}	a qcm	a Erg	η
15 380	23.62	9400	0.00188
14 700	21.04	8375	179
13 575	18,48	7355	180
11 875	14.62	5820	176
8 875	9,35	3720	179
6 700	5.80	2309	175
3 418	2.15	856	190
1 390	0.515	205	192

Aus dem Flächeninhalt f der Schleife wurde die Hysteresisarbeit a in Erg für 1 ccm Eisen ermittelt. η stellt den Steinmetzschen Koeffizienten $\eta = \frac{a}{B_{max}^{1,6}}$ dar. Der erste und die beiden letzten Werte unterscheiden sich nicht unwesentlich von den Werten 2 bis 6, welche in befriedigender Uebereinstimmung mit dem ersten Steinmetzschen Gesetz keine erhebliche Abweichung von ihrem Mittelwert $\eta_m = 0{,}00178$ aufweisen[2])

Die zweite Versuchsreihe, die Aufnahme

unsymmetrischer Magnetisierungszyklen,

schloß sich zunächst dem Steinmetzschen Vorbild an, indem bei 9 magnetischen Zyklen (vergl. Fig. 4 stets von demsel-

[1]) Gleiche Beobachtungen teilt Niethammer in der Elektrotechnischen Zeitschrift 1898 S. 685 mit. Während der Drucklegung dieses Aufsatzes erhielt der Verfasser von dem italienischen Physiker Vallauri in Mailand den Sonderabdruck eines von jenem kürzlich vor der Associazione Elettrotecnica Italiana gehaltenenen Vortrages, in dem ebenfalls das Problem der unsymmetrischen Magnetisierungszyklen eingehend und mit ähnlichen Ergebnissen behandelt wird.

[2]) Gumlich und Rose (ETZ 1905 S. 503 u. f.) haben bei ihren Versuchen für die größten und kleinsten Induktionen dieselbe Zunahme des Steinmetzschen Koeffizienten beobachtet.

DEFENDANT'S EXHIBIT AA. 1549

Translation of Extracts from "Boiler-House Reorganization"

By Richard Kablitz, Riga, in the "Zeitschrift des Vereines deutscher Ingenieure" Vol. 56, Oct. 26, 1912, pp. 1741–1746

In the following paper a report is made of the activities of a society for reducing the costs of steam production, which occupied itself under special conditions with the reorganization of boiler installations with a view to increased economy.

. 1550

Description of Plant

The boiler installation consisted of 16 double furnace boilers of 90 sq. m. heating surface, each divided into 2 groups of 8 boilers each. Fig. 1–3. Between the 2 groups were the feed pumps whose exhaust steam was utilized in pre-heaters. Each group used a chimney to which a common flue led; in this flue was hung a Kablitz economizer since no other space was available for it.

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(3) Kablitz Ribbed-tube economizers were hung directly in the flue (Fig. 1–3 and 7) and warmed the feed water up to 123°C. (253 deg. fahr.) by means of the gases. These 1551

economizers are installed in units of 70, 90, 110 and 132 sq. metres heating surface. For the rolling mill, 6 units of 70 sq. m. each were selected for each group (of boilers) because these corresponded best to the gas-velocity, the channel dimensions and other conditions. Every unit consists in the main of 3 parts: the upper distributor, the ribbed tubes screwed to the distributor, and the bends below connecting

1552 every 2 tubes. The water enters the first distributor, flows up and down through the whole row of tubes and comes out warm at the other end to pass on into the next unit. For cleaning, a steam blowing device serves, consisting of a portable iron frame with movable steam supply pipes which are let down between the ribbed tubes (Fig. 8). The steam (at about 60 lb. press.) discharges through small openings and frees the ribbed tubes of ashes and soot. The blowing, which, for a unit of 70 sq. m. heating surface takes about 1 min., is done every 6 hours.

Points in favor of this pre-heating by exhaust gases were its very reasonable price, its good utilization of heat in con-
1553 sequence of its compact and air-tight construction and of the fact that it hangs in the flue. Also the cheapness and simplicity of the brick-work construction and the quick installation were deciding considerations. Since no by-pass channel for the gas was provided, complete freedom from breakdown had to be assured, and this was ensured by the free-

dom for expansion obtained by hanging the economizer, and the fact that at any time a unit could be removed at noon and work go on undisturbed with the other units. This provision, however, was unnecessary except for cleaning the in-
1554 ternal scale and then the economizer is lifted out and the scale is freed in a relatively short time by an electrically-driven tube-cleaner even when there is a very hard deposit up to 10 mm. thick (Fig. 9). The feed-water was preheated on the average between 50° and 123°C. (122° to 253°F.) (diagram, Fig. 15) in which process the gas was cooled from 300°C to about 140° (572 to 284 deg. fahr.).

The heat transmission obtained was, K=9 kg. cals. per sq. m. per deg. cent. per hour, but on short trials and with high loads it sometimes rose to K=12. From this alone it is clear

that this figure is greatly dependent on the amount of gas supplied to the economizer. 1555

The draft loss in the economizer, determined by differential draught gauges, averages 4–5 mm. (.16 to .2 in.) of water

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To determine the saving the mill put a complete boiler-house record book in charge of an expert of the society. In

Boiler-House Reorganization –4b

it all the observations were recorded, so that the efficiency 1556
and the cost of steam might be definitely ascertained. The coal was examined at the same time in the laboratory of the Works and in the polytechnic institute at Riga; and the analyses agreed, because the same methods had been used.

The period of the guarantee for good material, free from defects, and for satisfactory construction extended to 2 years from the expiration of the test period, moreover a minimum saving during the test period was guaranteed and under its terms the rolling mill had the right to adjust payment. The same was true of doubtful results from tests.

After all the equipment was installed and the boiler-house in general was in order, the testing began and lasted about 1557
a year and a half, and was carried on by both parties at the same time. Its general outline follows: every half hour the amounts of water which had been turned into steam were read off from the water-meters, the water temperatures in front of the pre-heaters, in front of and behind the economizers, as well as the temperature of the gases and the number of boilers in operation recorded with their hours of work and the steam pressure were recorded. The quantity of coal was determined by weighing it on a scale and

1558 the samples were taken for analysis. The remaining ashes and clinkers were weighed also. Finally the draft above the

Boiler-House Reorganization –5b

grate was measured, also the draft loss in the boiler, in the economizer and at the foot of the chimney; they averaged 3, 6, 16 and 21 mm., water column.

Upon the basis of these data calculations were made monthly of the total quantity of water which had been converted into steam and of the total amount of coal consumed with reference to the previous heat values. From these the amount of evaporation was learned and after investigation
1559 of the average water temperatures, the quantity of heat obtained from the coal in producing 1 kg. of steam. With regard to the moisture content of the coal, which was determined every day, the average heat-value was found and then the efficiency of the boiler plant. Last of all the price of 1000 Kg. of evaporated water was counted up and from the month's quantity of water the whole saving was calculated.

The firemen's bonuses were counted in fixed steps, advancing according to the efficiency of the establishment and in this way the sum due was apportioned, chiefly according to hours of work, however, better firemen often receive more, at the expense of the poorer ones, according to the records
1560 of the official of the society who instructs them.

The results of the reconstruction were really very good as may be seen from Fig. 15.

Average of pre-heating in the pre-heaters was 50°–15° –35°C.

Boiler-House Reorganization –6b

Average pre-heating by means of the economizer was 123° –50°=73°C.

The efficiency rose from 55 per cent average to 72.4 per cent.

Defendant's Exhibit AA.

A city electricity plant was similarly rebuilt and shows an increase of efficiency of the boiler plant from 57 to 73 per cent. 1561

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The most important figures of the monthly records are repeated in Fig. 16.

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It is desirable to make the reconstruction of the boiler house complete, for the following reasons. In the transformation of coal heat into steam heat there are only 2 sources of loss which can be successfully dealt with.

First the loss from unburned (unconsumed) hydrocarbon and soot. 1562

. . . . . .

The second loss is the loss in the chimney gases which is a function of the temperature and of the quantity of gas.

. . . . . .

For the reduction of this loss the first step is to lower as much as possible the temperature of the gases by economizers because their action is independent of the fireman and because then there is no material gain in diminishing the excess of air or the quantity of gas.

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Translation of headings in figures in the article on Boiler House Reorganization in Z. V. D. I., Vol. 56, pages 1741 to 1746. 1563

Figures 1 to 3.

Aufstellung eines Rippenrohr-Rauchgasvorwarmers, Patent Kablitz, in 2 Gruppen von insgesamt 2 x 6 x 70=840 qm Heizflache in einen Panzerplattenwalzwerk. (Installation of Kablitz ribbed tube economizers in two groups, totalling 2 x 6 x 70=840 square meters of heating surface in an armor-plate rolling-mill.)

1564 Rauchgasvorwarmer 420 qm. (Economizers 420 square meters.)

Von den Speisepumpen. (From the feed pumps.)

Speisepumpen. (Feed pumps.)

Figure 7.

Rippenrohr-Abgasvorwarmer, Bauart Kablitz. (Kablitz ribbed tube economizer.)

Dampf zum Reinigen. (Steam to the tube cleaner.)

Verteilkorper. (Distributor.)

Rippenrohre. (Ribbed tubes.)

Verbindungskrummer. (Bends.)

1565 Translation of headings in figures in the article on Boiler House Reorganization in Z. V. D. I., Vol. 56, pages 1741 to 1746.

Figure 8.

Vorrichtung zum Reinigen des Abgasvorwarmers. (Arrangement for cleaning the economizer.)

Dampf. (Steam.)

Fahrbarer U-Eisenrahmen. (Portable U-shaped iron frame.)

Gelenkrohre. (Articulated pipe.)

5 Abblaserohre 20 mm. Dmr. (5 steam blow pipes of 20
1566 mm. diameter.)

Verteilkorper. (Distributor.)

Figure 9.

Elektrisch betriebener Fraser zum Reinigen der Rauchgas-Vorwarmerrohre. (Electrically driven tube cleaner for the economizer.)

Figure 15.

Diagram der Arbeit der Kesselanlage eines Panzerplatten-Walzwerkes vor dem Umbau und wahrend der Kontrollzeit vom 10, September 1909 bis 6. Juni 1911. (Performance

chart for the boiler plant of an armor plate rolling mill before the reconstruction and during the testing period from the 10th of September 1909 until the 6th of June 1911.) 1567

Vor dem Umbau. (Before rebuilding.)

Nach dem Umbau. (After rebuilding.)

Wassertemperatur vor dem Rauchgasvorwarmer. (Water temperature entering the economizer.)

Wassertemperatur hinter dem Rauchgasvorwarmer. (Water temperature leaving the economizer.)

Wirkungsgrad der Kesselanlage. (Efficiency of boiler plant.)

Translation of headings in figures in the article on Boiler House Reorganization in Z. V. D. I., Vol. 56, pages 1741 to 1746. 1568

Figure 16.

Diagram der Arbeit der Kesselanlage eines elektrischen Kraftwerkes vor dem Umbau und wahrend der Kontrollzeit vom. 1. August 1910 bis 31. Marz 1911. (Performance chart of the boiler plant of an electric power station before the reconstruction and during the testing time from August 1, 1910 to March 31, 1911.

Vor dem Umbau. (Before rebuilding.)

Nach dem Umbau. (After rebuilding.) 1569

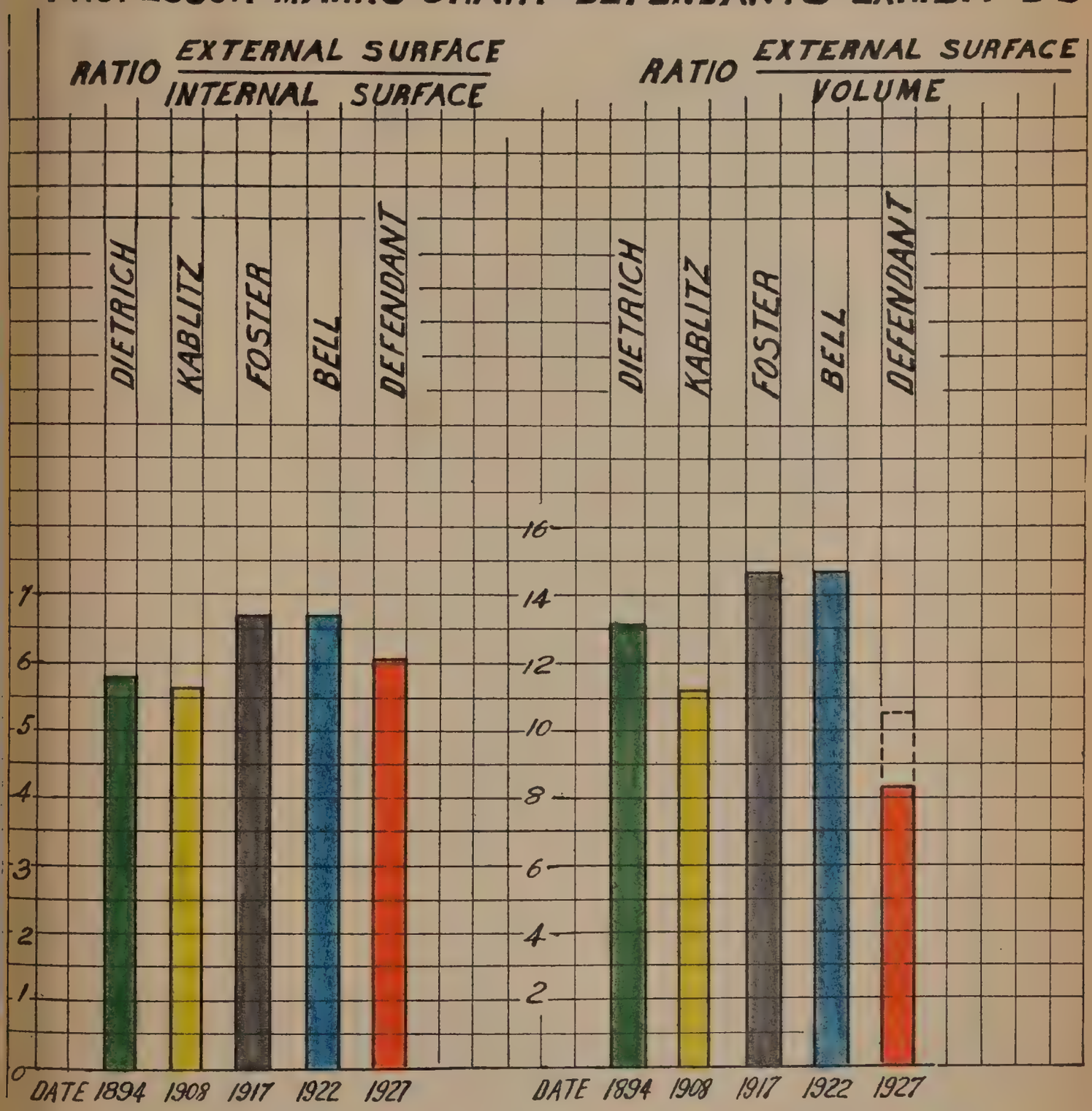
Wassertemperatur vor dem Rauchgaswarmer. (Water temperature entering the economizer.)

Wassertemperatur hinter dem Rauchgasvorwarmer. (Water temperature leaving the economizer.)

Ersparnis. (Saving.)

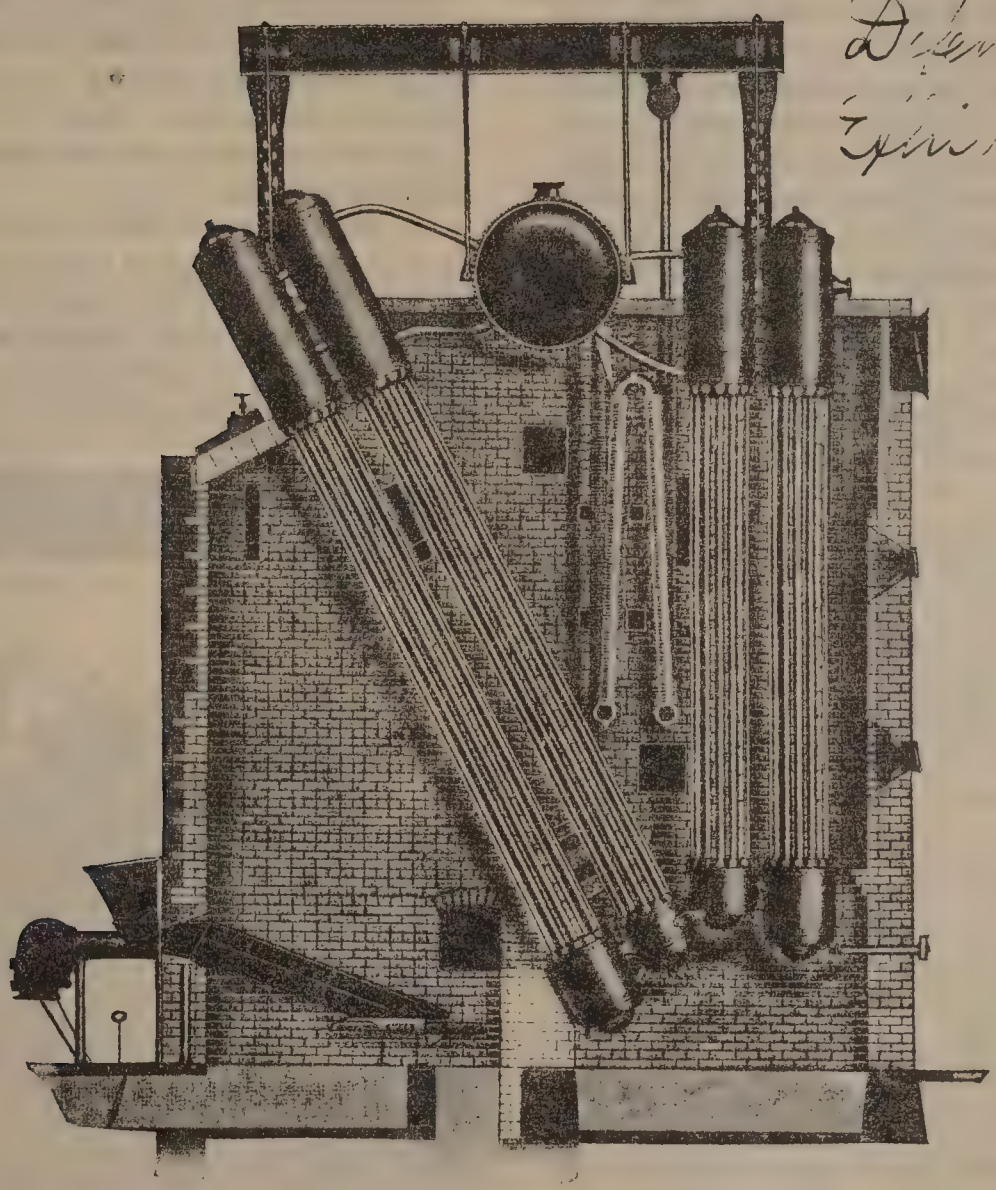
Wirkungsgrad der Kesselanlage. (Efficiency of the boiler plant.)

PROFESSOR MARKS' CHART-DEFENDANT'S EXHIBIT B B



Bigelow-Hornsby Water Tube Boilers

Delaware Exhibit Co.



The Bigelow Company

Established 1860

Main Office and Works:
NEW HAVEN, CONNECTICUT

New York
Singer Building

Philadelphia
Stock Exchange Building

Boston
Oliver Building

This pamphlet is issued to merely give the reader a general idea of the Bigelow-Hornsby Boiler, and Bigelow-Hornsby Integral Steel Economizer.

If interested, we earnestly request that more complete data be asked for.

The Bigelow-Hornsby Water Tube Boiler

THE BIGELOW-HORNSBY BOILER has the combined good features of a number of water tube boilers on the market, and it is designed along the correct theoretical lines of an economical heat-absorbing apparatus.

The draft loss for a given exit temperature is lower than usually found in other types of boilers, inasmuch as the reverse turns of the bases have been eliminated, and the draft loss is due entirely to the frictional resistance of the gases passing over the heating surface, rather than a large proportion of the draft loss being due to the change of direction of flow, as is usually encountered; also, the gases are split into thin streams while passing over the heating surface. The water enters the rear and passes toward the front, and the gases passing in the opposite direction gives true counter flow.

All tubes are straight (except the connecting nipples). These tubes are readily accessible, 21 tubes being uncovered by one 11″ x 15″ manhole opening, thereby not requiring a large number of tube covers to be removed, or the necessity of going inside of the boiler to have access to the tubes.

There is no internal staying or bracing, and all pressure is carried by wrought steel; that is, cast iron or cast steel is not depended upon for any pressure part.

The cut on the front page shows the side elevation of standard Bigelow-Hornsby Water Tube Boiler, and it will be noted that the boiler is entirely suspended from the overhead structural steel. There is a large furnace volume.

Absorption by radiant heat has been proved most efficient, and the Bigelow-Hornsby Boiler has a comparatively large proportion of the total heating surface directly exposed to the radiant heat of the furnace.

Figure I shows side elevation of the Bigelow-Hornsby Boiler, equipped with single bank Bigelow-Hornsby Integral Steel Economizer, which results in an increased efficiency, due to the lower temperature of escaping gases without the necessity of going to induced draft fans to overcome the draft loss, as is usually the case when economizers are installed. We have an installation of this arrangement of heating surface, developing 300% of rating, with a stack approximately 200 feet high.

Figures II and III show the plan and side elevation of arrangement, known as the converging type of heating surface. Of the total heating surface in this unit, approximately 19% is integral economizer surface. This arrangement of boiler and economizer is such that the cross-sectional area of each gas pass is decreased as it approaches the smoke flue outlet, and, as a result, the gases, as they become cooler approaching the smoke flue outlet, are increased in velocity in passing over the heating surface, thereby giving a maximum heat transmission with a minimum draft loss.

Figure IV shows side elevation of Bigelow-Hornsby Boiler, with Bigelow-Hornsby Preheating Surface installed, designed for burning oil or blast furnace gas. This is known as double bank 18 ft. economizer, and of the total surface in each unit approximately 35% is integral economizer.

The development of steel economizer heating surface has made very rapid strides in the past few years, and has met with a good deal of success, and doubtless will continue to, inasmuch as the designer and operator realizes that by installing the steel economizer it is necessary to remove the air, oxygen and carbon dioxide from the feed

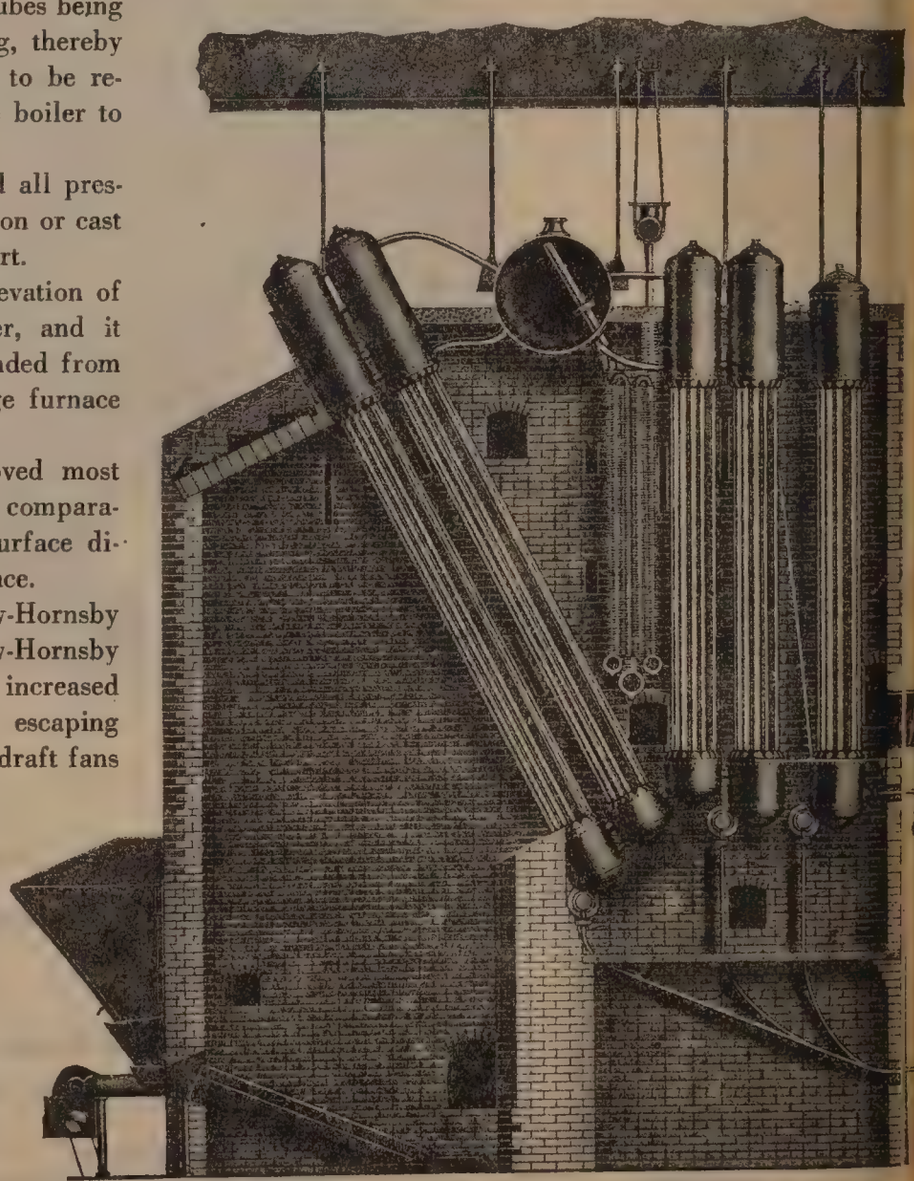


Fig. I
Bigelow-Hornsby Boiler with Single Branch Integral Steel Economizer

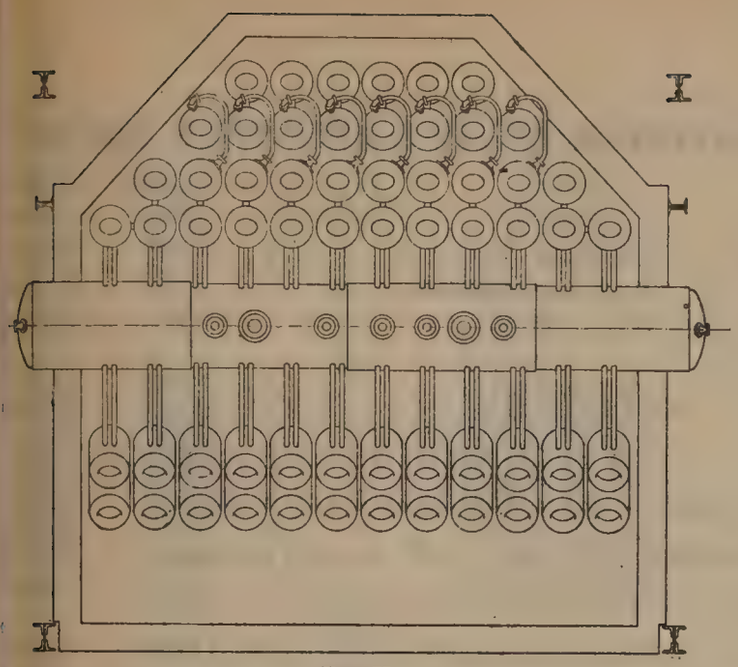


Fig. II

water before it enters the economizer, and the development of deaerators and deaerating feed water heaters has been very rapid, so that the cost of same is not at all excessive from what the normal requirements would be where steel economizers are not installed.

Figure V shows the installation of Bigelow-Hornsby Boiler with Powdered Coal Furnace, and it will be noted that the general arrangement of the heating surface to the furnace is almost ideal for powdered coal.

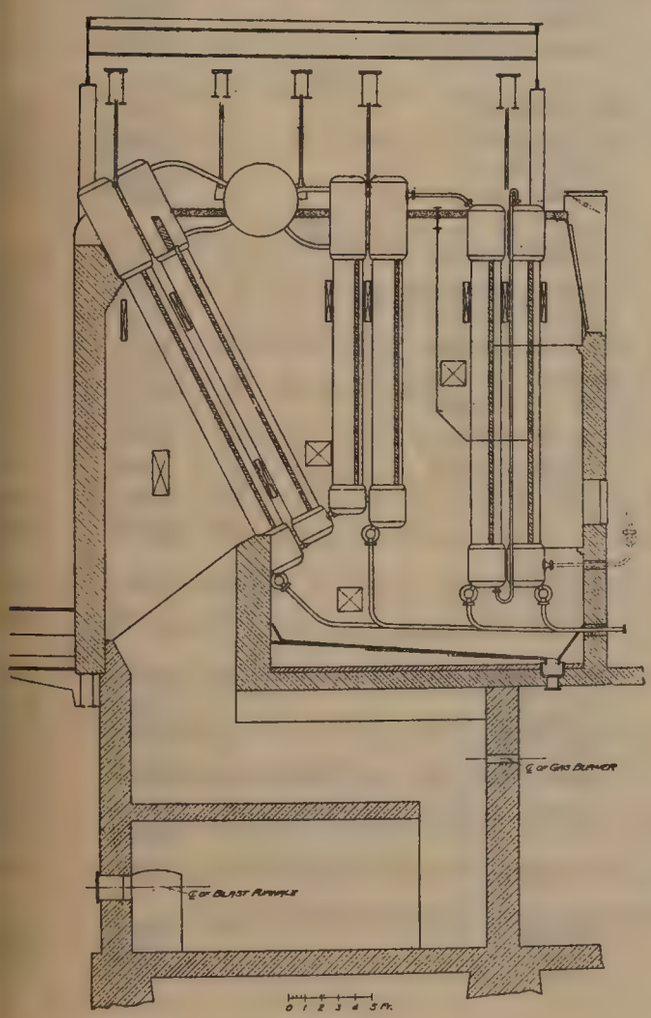


Fig. IV

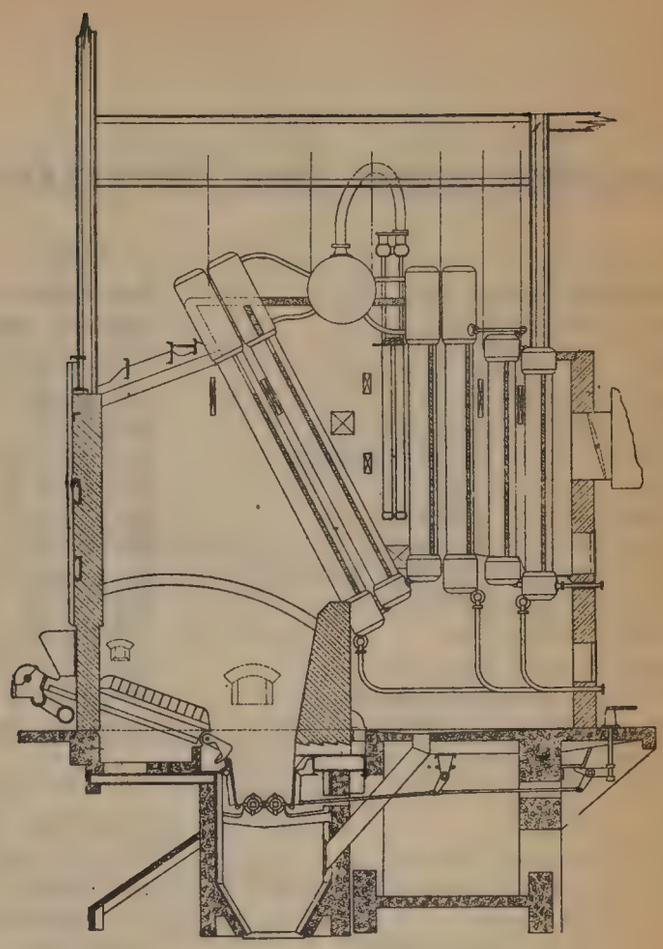


Fig. III

On the back page of this pamphlet we have given a list of some of the users of the Bigelow-Hornsby Boilers, which will doubtless be of interest, and we sincerely trust, as stated at the beginning of this pamphlet, if the reader is interested in the Bigelow-Hornsby Boiler, that he will get in touch with us for more complete data.

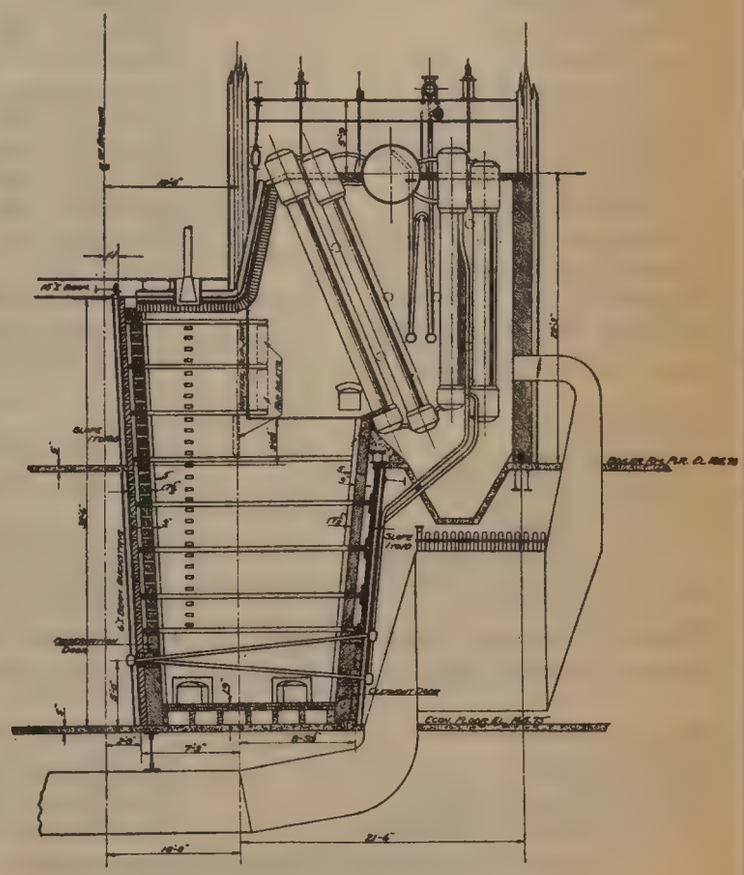


Fig. V

CONCERNS BELOW HAVE INSTALLED BIGELOW-HORNSBY WATER TUBE BOILER

Name.	Location.	Nature of Business.	No. of Orders.	No. of Units.	Htg. Surf. each.	Total Htg. Su
American Hardware Co.	New Britain, Conn.	Hardware Mfrs.	1	4	6156*	2462
Boston & Maine R. R.	Zylonite, Mass.	R. R. Electrification	2	6	5000	3000
Cherry River Paper Co.	Richwood, W. Va.	Paper Mfrs.	1	5	6329	3164
Henry L. Doherty & Co.	New York, N. Y.		10			
Ohio Public Service Co.	Lorain, O.	Central Station		3	18107*	5432
Public Service Co. of Colorado	Boulder, Colo.	Central Station		4	13320*	5328
Ohio Public Service Co.	Mansfield, O.	Central Station		1	10126	1012
Massillon Gas & Electric Co.	Massillon, O.	Central Station		2	5073	1014
Trumbull Public Service Co.	Warren, O.	Central Station		6	10126	6075
St. Joseph Ry., Lt., Heat & Power Co.	St. Joseph, Mo.	Central Station		2	10126	2025
Toledo Railway & Light Co.	Toledo, O.	Central Station		4	13924	5569
Toledo Edison Co.	Toledo, O.	Central Station		4	18107	7242
Electric Bond & Share Co.	New York, N. Y.		2			
Carolina Power & Light Co.	Moncure, N. C.	Central Station		5	11392	5696
Hartford Electric Light Co.	Hartford, Conn.		7			
Dutch Point Station		Central Station		10	12500	12500
South Meadow Station		Central Station		4	16929*	6771
Monument Mills	Housatonic, Mass.	Textiles	2	3	6250	1875
New Haven Gas Light Co.	New Haven, Conn.	Gas Works	3	6	3750	2250
New York, New Haven & Hartford R. R.	New Haven, Conn.		3			
Cos Cob Station	Cos Cob, Conn.	R. R. Electrification		14	6250	8750
Cedar Hill Power Station	New Haven, Conn.	Round-house		2	5000	1000
New York Steam Corp.	New York, N. Y.		2			
59th Street Station		Commercial Steam		3	17179*	5153
Niagara, Lockport & Ontario Power Co.	Lyons, N. Y.	Central Station	2	4	7500	3000
				3	10126	3037
Rochester Gas & Electric Corp	Rochester, N. Y.	Central Station	5	10	8750	8750
		Central Station		2	8861	1773
Rochester Gas & Electric Corp	Rochester, N. Y.	Commercial Steam		2	11219*	2243*
Standard Oil Co. of New Jersey	New York, N. Y.		4			
BayWay Refinery	BayWay, N. J.	Oil Refinery		4	18041*	7216
BayWay Refinery	BayWay, N. J.	Oil Refinery		4	9234*	3693
Canton Refinery	Baltimore, Md.	Oil Refinery		4	13121*	5248
Eagle Works	Eagle Oil, N. Y.	Oil Refinery		6	9841*	5904
Chas. H. Tenney & Co.	Boston, Mass.		13			
Fitchburg Gas & Electric Co.	Fitchburg, Mass.	Central Station		3	5000	1500
Fitchburg Gas & Electric Co.	Fitchburg, Mass.	Central Station		2	7595	1519
Haverhill Electric Co.	Haverhill, Mass.	Central Station		2	6329	1265
Haverhill Electric Co.	Haverhill, Mass.	Central Station		1	6250	625
Montpelier Power & Light Co.	Montpelier, Vt.	Central Station		2	6250	1250
Salem Electric Lighting Co.	Salem, Mass.	Central Station		8	7500	6000
Springfield Gas Light Co.	Springfield, Mass.	Gas Works		2	5000	1000
Torrington Electric Light Co.	Torrington, Conn.	Central Station	1	2	5063	1013
United Electric Railways Co.	Providence, R. I.	Street Railway	2	8	6250	5000
				3	12658	3797
U. S. Rubber Co.			4			
L. Candee Co.	New Haven, Conn.	Rubber Mfrs.		2	5063	1013
Hartford Rubber Works	Hartford, Conn.	Rubber Mfrs.		6	5000	3000
U. S. Steel Corp.			3			
American Steel & Wire Co.	New Haven, Conn.	Wire Mfrs.		4	5063	2027
American Steel & Wire Co.	Worcester, Mass.	Wire Mfrs.		6	5063	3037
National Tube Co.	Lorain, O.	Pipe Mfrs.		6	19492*	11695
Winchester Repeating Arms Co.	New Haven, Conn.	Arms Mfrs.	2	4	7500	3000
Worcester Electric Light Co.	Worcester, Mass.	Central Station	4	6	12500	7500
				3	12658	3797
Wuskanut Mills	Farnumsville, Mass.	Textiles	1	2	5063	1013
Yale University	New Haven, Conn.		2			
Central Heating Plant	New Haven, Conn.	Heating		5	5000	2500
Sterling Hall of Medicine	New Haven, Conn.	Heating		3	3797	1139

* Includes Bigelow-Hornsby Integral Economizer Surface.

OPINION.

1591

THOMAS, District Judge:

The bill in this case charges defendant with infringement of Letters Patent No. 1,565,305 granted to plaintiff on December 15, 1925 upon an application filed by John E. Bell on July 1, 1922 for a steam generating plant.

The defenses are the usual ones of non-infringement and invalidity by reason of anticipation by, and lack of invention over prior patents and publications and the prior art. It is also alleged as a further defense that the patent is invalid because of indefiniteness and uncertainty of the patent and the claim.

The defendant is engaged in the generation and sale of 1592
electricity with a large power plant located in Devon, Connecticut. The defense of this suit was assumed and conducted by The B. F. Sturtevant Company, which manufactured and installed in the defendant's power plant, an economizer which is charged to infringe claim 2 of the patent in suit.

Claim 2 is the only one in issue and it reads as follows:

> "2. The combination with a boiler and its furnace, of an economizer comprising a bank of horizontally disposed tubes externally swept by the heating gases leaving the furnace and through which feed water is passed 1593
> into the boiler, said tubes being each provided with external circumferentially extending ribs proportioned and disposed to make the external surface area of the tube several times greater than its internal surface area, and being each of a length many times greater than its maximum diameter, and being spaced to provide an external tube surface area per unit of space occupied by said bank which is several times greater than is practically possible with tubes which are of the same internal diameter and have smooth outer walls."

1594 It will thus be seen that the claim calls for a fuel economizer which is an apparatus for effecting coal economy in a steam generating plant by abstracting heat from the waste gases after they have left the boiler furnace and utilizing such heat to raise the temperature of the feed water before it enters the boiler. Or it may be defined as a device equipped with heating surfaces subjected to the furnace gases, just as the boilers, but separated from and above the boiler and receiving the feed water first. Devices of this type usually comprise a plurality of pipes or tubes, located in a passage or flue through which the hot waste gases from the boiler furnace pass to the stack or chimney. The ex-
1595 terior surfaces of the pipes or tubes are exposed to the departing gases and absorb heat which in turn is transmitted to the feed water within the tubes as it passes through the economizer on its way to and before it enters the boiler tubes. For obvious reasons it is desirable to expose as large a surface of metal to the heat of the gases as possible. To secure this advantage it was proposed many years prior to the filing date of the application which resulted in the patent in suit, to corrugate the exterior of the tubes as is shown in the Kablitz patent No. 886,516 issued May 3, 1908; French patent No. 237,583 dated April 7, 1894; and United States patent No. 1,239,377 to Foster dated September 4, 1917,
1596 which was assigned to this plaintiff. A further desideratum of steam economizers is the flow of water through the tubes downward in a direction opposite to the flow of the furnace gases which is upward and against the tubes. This feature has long been recognized by those working in the art as is shown in the Foster patent just mentioned. The invention there disclosed relates to a fuel economizer and one of its important features consists in arranging the economizer so that the feed water is introduced at the top of the boiler and by aid of gravity zigzags back and forth across and down-

ward in counter current to the rising gases so that the highest temperature of the feed water is at the point where it enters the boiler proper. 1597

Bell was an engineer in this art for a number of years and was fully aware of the actual and practical economizer art and of the prior patents relating to it as well as the general state of the art and had taken out various patents relating to steam engines. In the patent in suit he assembled old elements in a new organization of parts so as to produce a more beneficial result. He recognized that high draft resistance in the passage or flue leading to the stack or chimney of a boiler,—always recognized prior to his invention as a 1598
waste,—could be converted into a profitable investment. Appreciating that the rate of heat transmission to the economizer tubes varies proportionately with the velocity of the flow of the hot waste gases over the tube surfaces, Bell made the discovery that, by combining extended surface tubes with the closest possible spacing of such tubes, a close rubbing contact of gases on metal and consequently a high rate of transmission, as well as high draft loss, would be produced. Bell accepted this loss because he appreciated that with his structure there is developed an increase in the rate of heat transmission which more than compensates for the draft loss. He realized that the provision of extended surface tubes 1599
alone would not be sufficient and that the compacted heating surface, so arranged and disposed and spaced that it obstructs the draft, results in a highly efficient economizer.

The Bell construction, as described in the patent in suit, combines with a boiler and its furnace an economizer which comprises a bank of horizontally disposed tubes provided with external circumferentially extending heat absorbing ribs. The feed water passes through these tubes into the boiler in a direction opposite to that of the waste gases. The external ribs on the tubes are so proportioned and dis-

1600 posed as to make the external surface area of the tubes several times greater than their internal surface area. Each tube is of a length many times greater than its maximum diameter. The tubes are spaced to provide an external tube surface area per unit of space occupied by the bank of tubes which is several times greater than is practically possible with tubes which are of the same diameter and have smooth outer walls. The economizer is characterized by its compactness, which not only reduces the bulk and initial cost of the economizer but makes it feasible to enclose the economizer in a housing which forms part of the boiler and is sufficiently air tight to eliminate air leakage into the economizer, not-
1601 withstanding the high draft suction required to move the heating gases through the boiler and economizer.

Defendant contends that claim 2 is invalid in view of the prior patented and published art and also in view of the prior unpatented art, but is unable to point out anything in the art which discloses the principle of draft loss in the operation of an economizer. It is true that claim 2 does not specifically mention such draft loss. It does, however, call for an organization and arrangement of the economizer tubes which result in a draft loss,—a beneficial result not obtained prior to Bell's invention.

1602 Even if it be admitted that all the elements of plaintiff's device are old, per se, yet there may be invention where they are organized in a new and useful manner so as to produce a more beneficial result. This was the rule laid down by Judge Severance, speaking for the Circuit Court of Appeals for the Sixth Circuit in *Western Electric Co.* v. *North Electric Co.*, 135 Fed. 79. On page 89 he said:

> "All three of these patents may well stand upon the rule which has several times been affirmed by this court, namely, that while the mere assembling in a new organization of parts of old structures to perform the same

function in their new place that they did in the old is not invention, yet where they are so taken and are organized in a new and useful manner, so as to produce a more beneficial result, there may be invention; and when the combination displays the exercise of intuitive skill and genius beyond that possessed and exercised by those well skilled in the practice of their art, and the discovery is of something new and useful, invention should be recognized." 1603

Defendant also argues that claim 2 is void because it is indefinite in that it fails to comply with the statute and because it abounds in indefinite and uncertain phrases. There 1604 seems to be no merit to this contention because it has long since been settled that if the terms in which a claim is stated are consistent with those of the description, the specification with its accompanying drawings is treated as an amplification and explanation of the claim illustrating and applying its more concise and definite expressions. A claim should be sustained whenever in connection with its proper exponent,—the description or specification,—and in view of the state of the art, it renders the nature of the claimed invention evident to those to whom the specification is addressed, and, of course, that means to those who are skilled in the art. It cannot be denied that the patentee's description,—that is 1605 to say, the specification of the patent apart from its claims, —refers to the several phrases to which defendant takes exception on account of indefiniteness, disclosing many examples of embodiment of the invention, so that the said claim is far from being indefinite when reference is had to the specification. The claim covers, therefore, every feature of the invention which the description has declared to be essential and all the modes of using it therein described. In view of the foregoing it is held that claim 2 in suit is valid.

1606 INFRINGEMENT.

There is no dispute as to the construction of the economizer manufactured and installed by The Sturtevant Company and used by the defendant in its generating plant at Devon. It is admitted that such construction is correctly illustrated in plaintiff's Exhibits 2, 2A, 2B, 2C and 2D. The evidence adduced in connection with these exhibits convinces me that defendant's device comes within the terms of the claim in issue, because the defendant's construction embodies the elements recited in the claim in the same combination, location and arrangement. Defendant in comparing
1607 tube surface area of its tubes per unit of space occupied by the bank of tubes with the disclosure of the patent, includes the space between the tube banks, occupied by soot blowers, and consequently arrives at a figure which differs from that mentioned in the patent. However, it is evident that "external tube surface area", as used in the claim, means "external heat absorbing surface" and "per unit of space occupied by said bank" means any unit of volume of the heat absorbing surface of the tubes. By no means does it mean space occupied by soot blowers or any other apparatus. Defendant points out other differences between its economizer and that disclosed in the patent in suit. These differences,
1608 however, are really improvements upon plaintiff's construction. Of course, defendant has the right to make improvements upon plaintiff's combination. However, inasmuch as these improvements do not present a new combination of the elements found in plaintiff's patent they do not avoid infringement.

Plaintiff is entitled to the usual decree for an injunction, reference, accounting and costs, and it is

So ordered.

August 1, 1928.

1609

STIPULATION AS TO RECORD.

It is hereby stipulated and agreed that the following is a true transcript of the record of the said District Court in the above-entitled matter as agreed upon by the parties, subject, however, to correction by either party should error therein appear.

It is further stipulated and agreed that the clerk send to the clerk of the Court of Appeals for the Second Circuit for safe keepting and use in the argument on appeal all of the original exhibits, both physical and documentary, offered by either or both parties. 1610

WILLIAM G. McKNIGHT,
Counsel for Plaintiff-Appellee.
ALFRED H. HILDRETH,
Counsel for Defendants-Appellants.

November 19, 1928.

CLERK'S CERTIFICATE.

I, C. E. Pickett, Clerk of the District Court of the United States of America for the District of Connecticut, do hereby certify that the foregoing is a true transcript of the record of the said District Court in the above-entitled matter as 1611 agreed upon by the parties.

In testimony whereof I have caused the seal of said court to be hereto affixed at New Haven, Connecticut, this 22d day of November, 1928, and of the independence of the United States the one hundred and fifty-third.

[SEAL] C. E. PICKETT, *Clerk.*

United States Circuit Court of Appeals

FOR THE SECOND CIRCUIT.

POWER SPECIALTY COMPANY,

Plaintiff-Appellee,

vs.

THE CONNECTICUT LIGHT & POWER COMPANY

AND

B. F. STURTEVANT COMPANY,

Defendants-Appellants.

BRIEF FOR DEFENDANTS-APPELLANTS.

CHARLES NEAVE,
ALFRED H. HILDRETH,
MELVIN R. JENNEY,
Of Counsel for Defendants-Appellants.

December, 1928.

The Evening Post Job Printing Office, Inc., 154 Fulton St., New York, N. Y.

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United States Circuit Court of Appeals

FOR THE SECOND CIRCUIT.

POWER SPECIALTY COMPANY,
Plaintiff-Appellee,

vs.

THE CONNECTICUT LIGHT & POWER COMPANY and B. F. STURTEVANT COMPANY,
Defendants-Appellants.

BRIEF FOR DEFENDANTS-APPELLANTS.

This appeal is from the District Court in Connecticut, Judge Thomas sitting. The decision was in favor of the plaintiff (Rec. p. 531).

The suit is upon claim 2 of Bell patent 1,565,305 for a "Steam Generating Plant" (Rec. p. 175).

The Connecticut Light & Power Company is the user of the plant which has been held to be an infringement. The other defendant, the B. F. Sturtevant Company, is the manufacturer of apparatus in that plant.

The General Subject Matter in Controversy.

In a plant for generating steam there are, of course, a boiler containing the water to be converted into steam, and a furnace for heating that boiler. The hot gases, resulting from the combus-

tion of fuel in the furnace, pass first through the boiler and then go out the chimney or stack.

In order to utilize some of the heat still contained in these gases after they have passed the boiler, it has long been the practice to insert in the passage leading from the furnace to the stack, some tubes through which feed water may pass on its way to the boiler; thus some of the otherwise wasted heat of the gases is utilized in heating the feed water. Obviously, the warmer the feed water when it enters the boiler, the less fuel will be required to raise its temperature to the point at which it is converted into steam.

These feed water heaters are called "economizers", and were so known and were used long prior to the alleged invention in suit.

The Patent in Suit.

The patent in suit states (Rec. p. 175, line 12) that "the object of my invention is to provide for *the more effective utilization of an economizer* for transferring heat to boiler water from the partially cooled products of combustion leaving the boiler furnace".

The patentee recognizes that he was not the first to use such an economizer, for the patent states (p. 1, line 18) that "it has long been common practice to preheat boiler feed water by the use of an economizer". But the patent proceeds to state (p. 1, lines 20-32) that

> "heretofore the economizer has ordinarily been regarded as an adjunct of the boiler, which, while of value, is distinctly of secondary importance as compared with the boiler proper. I have discovered, however, that highly beneficial results, both with respect to the thermal efficiency and operating economy of a steam generating plant, and with respect to the

initial construction and maintenance costs, may be obtained by making the economizer a more important element of the steam generating plant than has heretofore been the case."

And, at lines 83 to 102 of page 1, it is further stated:

"Heretofore in ordinary practice, the ratio of economizer heating surface to boiler heating surface has not been greater than the ratio of 7 to 10. In accordance with my present invention I make the economizer heating surface at least as great as and in some cases considerably greater than the boiler heating surface. In thus increasing the ratio of economizer to boiler heating surface in a steam generating plant of given capacity, I make the amount of economizer heating surface greater and the amount of boiler heating surface smaller than has heretofore been used in a steam generating plant of similar capacity and efficiency. The increase in economizer heating surface made is less however than the decrease in boiler heating surface as my invention permits of a smaller aggregate boiler and economizer heating surface than has heretofore been required."

Of course the economizer, whether large or small, whether with widely spaced tubes or compactly arranged tubes, obstructs the passage in which it is placed between the furnace and the stack. If it is small, that obstruction is not great, and the gases are not much retarded in their passage to the stack, so substantially no stronger draft is required to carry the gases through the economizer. If, however, the economizer is large and compactly built so that there are only comparatively small passages through it, the draft suction must be larger to pull the gases through it and, possibly, the natural draft will not be enough and a fan may have to be used to supplement the natural draft—such an expedient being admittedly a very old one (p. 51, folio 153).

The patent, after speaking of the patentee's proposal to make the economizer a more important element of the steam generating plant than has heretofore been the case, states (p. 1, lines 33-43):

> "To this end I substantially increase the ratio of economizer heating surface to boiler heating surface over that heretofore employed in commercial practice, and provide the economizer heating surface in an economizer of special construction characterized by its compactness and requiring a draft much stronger than is required in the types of economizers heretofore in use to move the heating gases through it."

As to the construction of the economizer, the patentee states (p. 1, lines 44 to 50) that he uses tubes

> "similar in construction to those *heretofore* employed in the well known Foster superheater, in that each tube comprises an inner tube of wrought steel which is surrounded by an externally corrugated tubular cast iron casing".

These "well known" Foster "superheater" tubes are shown in Foster patent 963,732 of 1910 (Rec. p. 418). The arrangement, as there described, consists of a tube surrounded by cast iron rings having projecting annular fins, or "gills".

A "superheater" is to increase the temperature of the steam after it is formed, by transferring heat from the surrounding hot gases to the *steam* inside of the pipes. An "economizer" is to increase the temperature of the water before it reaches the boiler, by transferring heat from the surrounding hot gases to the *water* inside of the pipes. The transfer of heat is the same in each case; only the fluid to be heated is different.

These same Foster tubes were old in economizers long before the invention in suit, as shown

in the Foster patent 1,239,377 of 1917 (Rec. p. 426), a perspective view of the economizer tube arrangement being shown at page 495. In the Foster patent it is stated (p. 1, lines 20-40):

> "Another of the more important features of the invention consists in employing independent cast metal rings in contact with each other and fitting snugly on the economizer tubes so that the absorption of heat energy of the gases of combustion by the water flowing through the economizer tubes will be as complete as possible. This means that the heat must pass from the gases to the metal comprising the tube and thence from the metal to the water. The rate of heat transference between a gas and a metal differs from the rate between water and a metal, being much greater in the latter case. In order to compensate for this difference it is necessary to provide a larger contact surface between the gas and the metal, where the transference is slow, than between water and the metal where the transference is relatively rapid."

So it was old, as the patent in suit thus recognizes by its reference to the Foster construction, to cause the tubes to have a large external heating surface by the use of fins, or gills, or corrugations, so as to get an efficient transfer of heat.

The patent in suit then proceeds (p. 1, lines 50-58):

> "In the economizer which I employ, the special tubes are preferably spaced closely enough together to give an aggregate external tube surface area per unit of volume of space occupied which is several times greater than is obtained or is practically possible of attainment in economizers of the types heretofore in commercial use."

This seems to mean merely that the patentee proposes to use the old Foster tubes close together, and thus make a compact structure; but this was

old, as we shall see. Then the patentee seeks to attribute some advantages to his construction which, however, are precisely the advantages specified in the prior Foster economizer patent. The patent in suit states (p. 1, lines 68 to 82):

> "The special economizer tube construction employed provides a very large amount of external heating surface swept by the heating gases, in comparison with the internal wet surface of the tube; is well adapted for high pressure work since the steel inner tube may readily be of sufficient strength to resist an internal pressure as high or higher than the boiler steam pressure and the cast iron casing section protects the steel inner tube from the corrosive effect of the furnace gases which rapidly destroy steel economizer tubes directly exposed to the action of the heating gases, especially in the low temperature portion of an economizer."

The *prior Foster Economizer patent* similarly states (p. 1, lines 39-85):

> "Thus by providing an economizer tube with a large external as compared with internal surface, a higher efficiency or transference capacity is obtained than if ordinary cylindrical wall tubes were used, as has been the custom heretofore.
>
> "This construction permits the use of two kinds of metals in making economizer tubes which in turn enables the application of economizers to high steam pressures. Economizer tubes as now commonly employed are made from cast iron because the resistance of the latter to attacks from gases of combustion and from the corrosive or pitting tendency of hot water which passes through the tubes. Cast iron tubes are not reliable unless made with relatively thick walls which implies more weight and requires more space than if a more reliable or stronger metal is used. On the other hand tubes made from the stronger and more reliable metals, such as steel and wrought iron, have proven unsuccessful as economizers

because of their short life due to the corrosive effect of gases and water. Then again modern practice is constantly requiring higher steam pressures and up to approximately 200 lbs. per square foot cast iron economizers have been used successfully, but at higher pressures cast iron is unreliable for this purpose, with a result that one is forced to use steel or wrought iron tubes or else abandon the use of economizers entirely, which would not only be a serious loss to power plant economy but necessitates the burning of more fuel. My invention therefore contemplates the use of non-corrodible tubes, such as copper or brass, covered with cast iron external protection surfaces with the beneficial result of the water, which has a corrosive action, coming into contact with a non-corrodible surface forming the body of the tube, and with the further result that the gases of combustion come in contact with the cast iron exterior which has excellent durability or resistance against the detrimental action of said gases."

As the economizer obstructs the passage of the gases to the stack, providing at that point a smaller opening for the gases to get through, of course the gases will necessarily pass through the economizer at a higher velocity than if no obstruction were there—otherwise the same volume of gas could not get through the smaller hole. This increase of velocity means that the draft has been impeded—a draft loss, which may necessitate the use of a fan to draw the gases through. But this increased velocity is not an unmixed evil, for, as was well known, the gases part with their heat more rapidly when moving over a surface at high velocity. Thus, the patent in suit states (p. 2, lines 13-19):

"The rate at which a heated gas gives up its heat to a cooler surface is, *as well known,* almost directly proportional to the velocity of flow of the gas over the surface, or more strictly speaking, to the product of the velocity times the gas density, or the mass flow."

Then, as to the construction of the economizer, the patent in suit states (p. 2, lines 63-88):

> "The tubes should be horizontally disposed to restrict the tendency of furnace dust to deposit on the sides of the corrugation ribs and to facilitate cleaning the tube. Furthermore, the tubes should extend transversely to the direction of flow of the heating gases and should be arranged on rows substantially transverse to the direction of flow of the heating gases; with the tubes in adjacent rows staggered; and the tubes should be closely spaced so that the average distance between tube centers is small, for example in the neighborhood of one and one quarter times the maximum tube diameter, and the area of the gas path between a pair of adjacent tubes in adjacent rows transverse to the direction of the gas flow should not be less than one half the area of the gas path between adjacent tubes in the same row, to insure proper contact between the heating gases and the tubes, and to minimize the frictional resistance to the flow of the heating gases through the economizer and thereby minimize the draft required to move the heating gases through the bank of the economizer tubes."

The patent then suggests that it may be desirable under some conditions to pass only a portion of the gases through the economizer (p. 2, lines 89-111). Then it is pointed out that the temperature of the water in the tubes should increase progressively from the initial water temperature at the top to the maximum temperature at the bottom (p. 2, lines 112-121) and then (p. 2, lines 121 to p. 3, line 5):

> "To obtain this result it is not only necessary to have the water flow back and forth through economizer tubes at successively lower levels, but it is also necessary, as I have discovered, to have a velocity of water flow through the economizer tubes which is not less than a certain critical velocity. If the velocity of the water flow is less than this critical velocity

> parasitical or convection currents will be set up in the water in the economizer tubes which will make the temperature in the tubes at the top of the back practically as high as the temperature in the tubes at the bottom of the bank."

The patent then points out that when the conditions of operation are such as to maintain a fairly definite water temperature gradient, the water temperature at which the tubes are attacked by corrosion is localized at one or two tubes, and it is then stated (p. 3, lines 39-49):

> "By arranging and operating an economizer so that this critical water temperature of 180° or so, is normally maintained in the economizer tubes in one or two rows only, and making the tubes subject to this corrosive action readily removable, it follows that the destructive effect of air in the water is restricted to a comparatively few number of tubes which may be readily replaced without disturbing the large majority or uninjured tubes."

Then follows a distressingly long and detailed description of the drawings—a description replete with repetition of what had gone before. It is pointed out (p. 5, lines 56-64):

> "This heat absorbing capacity is of course greatly enhanced by the relatively great amount of external heating surface in contact with the furnace gases which it provides. The area of external gas swept heating surface of each tube may advantageously be in the neighborhood of 5½ to 6½ times as great as in the internal wet surface area of the tube."

Such increased area due to the circumferential ribs is exactly what Foster had previously pointed out (pp. 6-7, *supra*).

Then the patent states that the tubes are "staggered" (in which there is admittedly nothing new, p. 51, folio 153) and "are closely spaced" (p. 5, line 73) which, as we shall see, was old.

The Claim.

Claim 2, the only one in issue, is as follows and, in copying it, we have broken it up into paragraphs to make it easier.

> "2. The combination with a boiler and its furnace, of an economizer comprising
>
> "a bank of horizontally disposed tubes externally swept by the heating gases leaving the furnace and through which feed water is passed into the boiler
>
> "said tubes being each provided with external circumferentially extending ribs proportioned and disposed to make the external surface area of the tube several times greater than its internal surface area,
>
> "and being each of a length many times greater than its maximum diameter,
>
> "and being spaced to provide an external tube surface area per unit of space occupied by said bank which is several times greater than is practically possible with tubes which are of the same internal diameter and have smooth outer walls."

The claim is purely for a structure. It proposes economizer tubes placed where they always have been placed, having external ribs (such as they long had had) providing the larger external surface which they were always designed to provide and did provide; and it is proposed to place these tubes close together.

The claim comes as a decided anti-climax to the verbose specification in which emphasis is laid upon many things not in the claim at all.

The thing that the patentee has "discovered" as to the beneficial results of making the economizer a more important element of the steam generating plant than it previously was, so that "in accordance with my present invention I make the economizer heating surface at least as great as and in some cases considerably greater than the boiler heating surface" (p. 1, lines 24, 86-90)—all that is lost sight of in the claim. *The economizer heating surface of the claim may be large or small, both absolutely and with reference to the boiler surface.*

The steel tube surrounded by an externally cast iron casing emphasized in the specification (p. 1, lines 45-50, 72-82) is lost sight of in the claim. *The tubes of the claim may be of any material and construction so long as they have external circumferentially extending ribs to make the external surface area several times greater than the internal.*

The tubes may be staggered *or not,* and still be within the claim.

Having the feed water enter at the top and flow out at the bottom (instead of *vice versa*) and a "critical" velocity of flow of the water, and the fairly definite water temperature gradient insisted on in the specification (p. 2, lines 112 to p. 3, line 49), are lost sight of in the claim. *The tubes of the claims are to be horizontal (so as to restrict dust deposit and facilitate dust removal, p. 2, lines 63-66), but the water may flow up or flow down, in the direction of movement of the gases or against it, and at any velocity and any temperature gradient.*

The claim specifies that each tube shall have a length "many" times greater than its maximum diameter. But what this has to do with principle of operation, we do not know; and the specification does not tell us.

And, as admitted by the plaintiff's witness (p. 167, folio 500), *the economizer of the claim may have either a high draft loss or a low draft loss.*

The claim is purely for a structure—a structure in which there was nothing new.

Prior Economizers with Tubes Having Ribs.

The use of horizontally disposed economizer tubes having external circumferentially extending ribs, or "gills", to increase the external surface area subjected to the gases was well known.

This is shown in the *Dietrich* French patent 237,853 of 1895 (Rec. p. 445), the drawings being at pages 439-443. A perspective drawing is at page 489. For convenience, Fig. 3 of the patent drawings and the perspective drawing are here reproduced.

The patent (which *was not cited* during the prosecution of the application for the patent in suit) states, in describing what is shown by the drawings (Rec. p. 446):

> "Figure 3 an economizer arranged in sequence to the above mentioned boiler in the gases which go from that boiler to the chimney."

And, on the preceding page the patent states that the tubes are provided with disks and that

> "Such disked tubes will permit the assembly of a very considerable heating surface in a small volume and permits the arrangement of boilers in a very restricted space."

A very compact economizer, in other words. Here are horizontal tubes with external ribs giving a very much extended heating surface for a given space, each tube having a length many times its maximum diameter. And it is apparent from the

DIETRICH FRENCH PATENT Nº 237,583

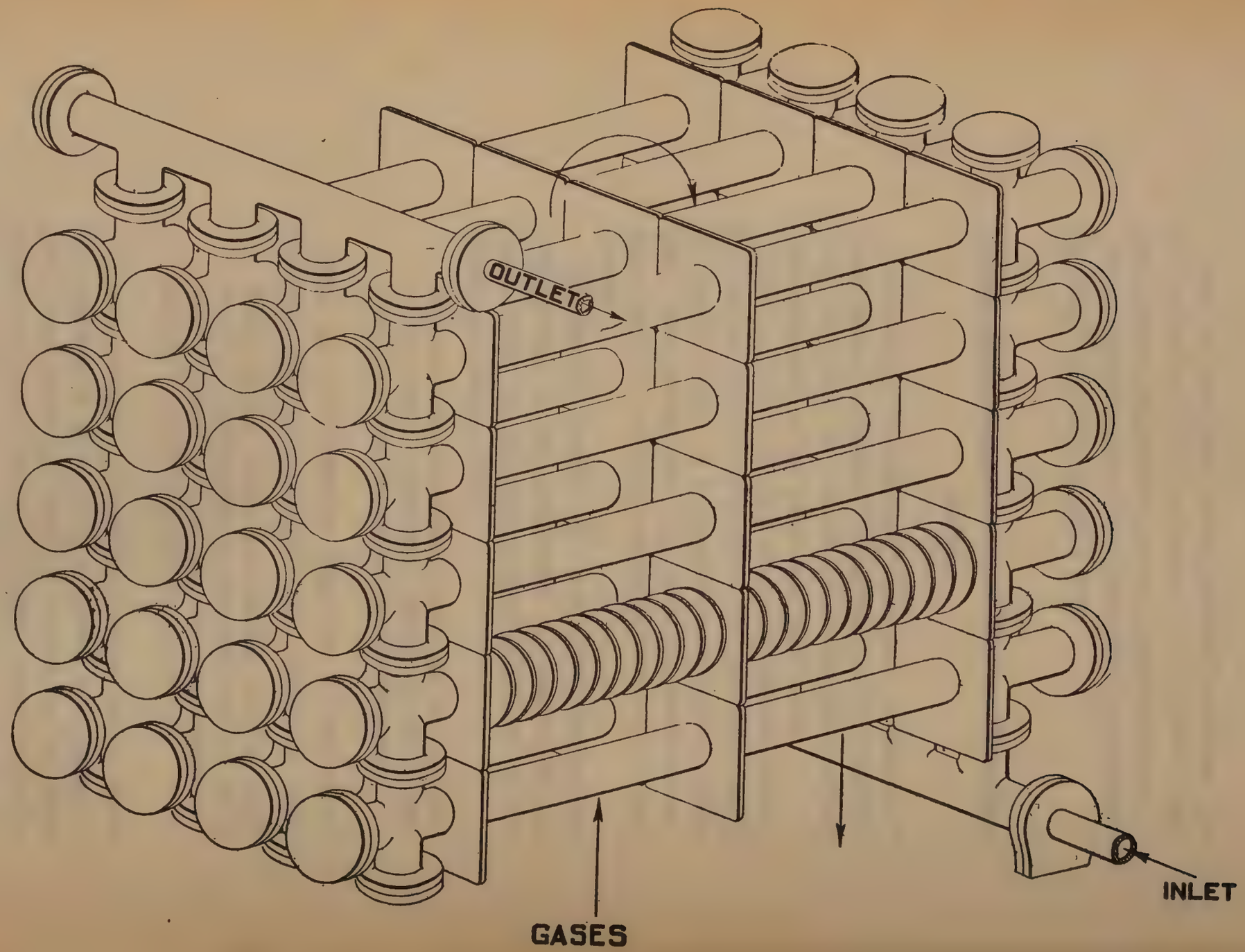
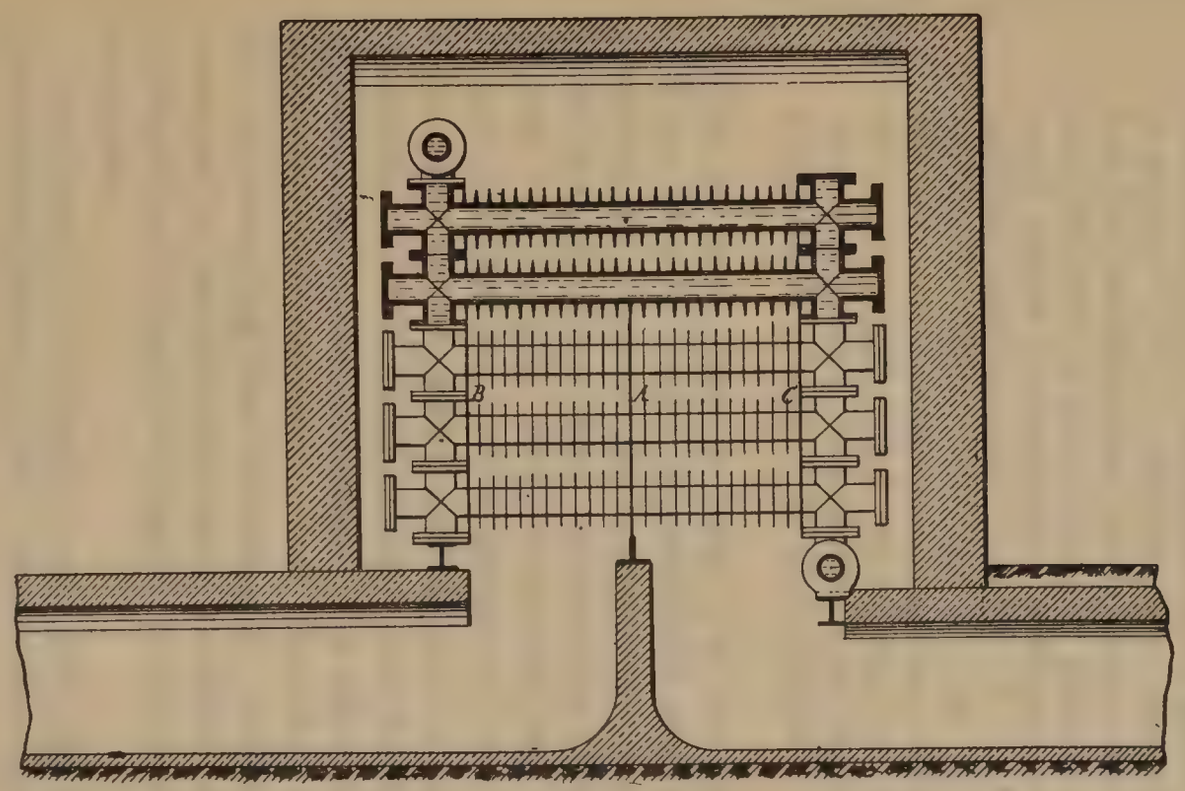
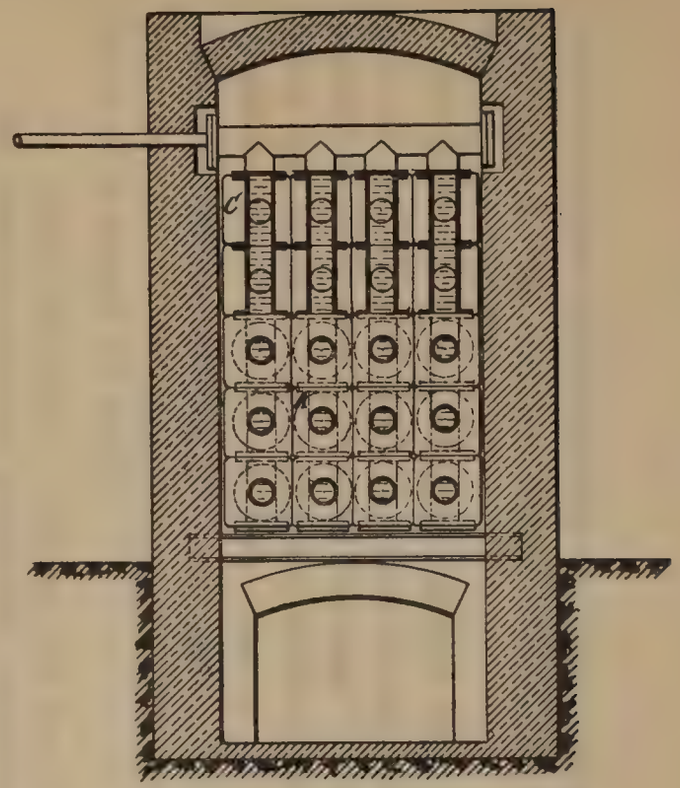
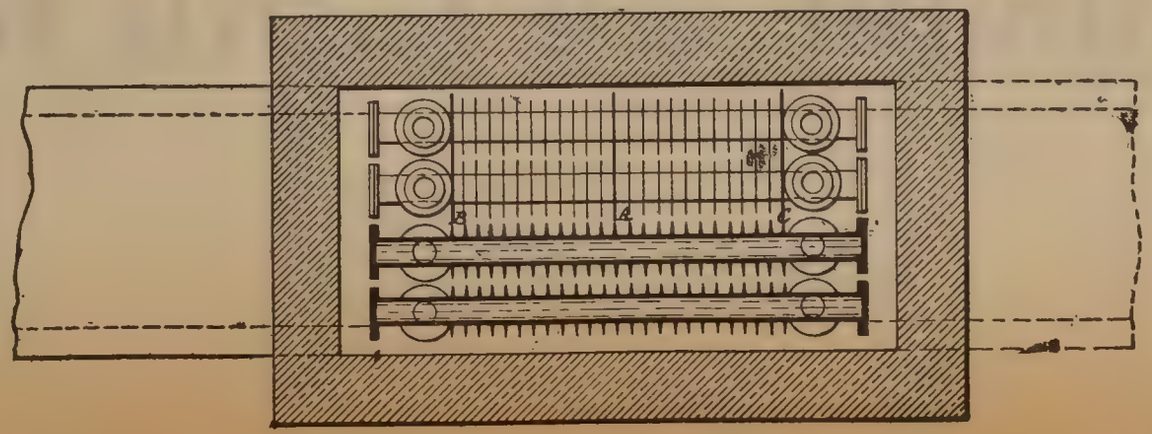


Planche III

RECHAUFFEUR D'EAU D'ALIMENTATION D'UNE CHAUDIERE A VAPEUR







Niederbronn le 30 Mars 1894

pp. L. Dietrich & Cie

Ch. de Dietrich

Dietrich patent drawings that the tubes are as near together as they can be without having the flanges actually in contact.

The idea of having circumferential ribs to provide an extended external heating surface was definitely worked out in a 1908 German publication (Rec. pp. 503-507) describing the economizer of the *Kablitz* patent 886,516 of 1908 (Rec. p. 411). In that publication (which *was not cited* during the prosecution of the application for the patent in suit) it is stated (p. 505):

> "A large absorption surface for the heat of the gases is created by ribbing the tube. The heat conductivity coefficient of the gases * * * is small * * *. On the other hand the surface for the delivering of the heat to the water may be *several times* smaller because of the much larger transmission coefficient and the uniform washing over by water * * *. The surface in contact with the gas, or the ribbed tube surface, should then be at least 1000:20 = 50 times larger than the surface in contact with the water. The ribbed tube is therefore particularly adapted for this purpose."

That is, as is stated in claim 2 of the patent in suit the tubes are "each provided with external circumferentially extending ribs proportioned and disposed to make the external surface area of the tube several times greater than its internal area."

And each Kablitz tube is, obviously, of a length many times its external diameter, and the tubes are staggered and are arranged very close together. It is true that in this economizer the tubes are vertical instead of horizontal. But, there was no novelty in arranging them horizontally; they were so arranged in the Dietrich patent to which we have referred, and in the Foster patent to which we shall next refer.

Incidentally, it is well to note that the Kablitz publication states (p. 507) that baffles are so ar-

ranged that the gases are made to pass the pipes several times *"so as to obtain high gas velocity"* which is referred to in the patent in suit as "well-known" (p. 7, *supra*) though it does not enter into the claim.

The *Foster* economizer patent 1,239,377 (to which we have already referred, pp. 5-7, *supra*) likewise has horizontally disposed, ribbed tubes, each tube having a length many times greater than its maximum diameter. The patent is at page 426 and an enlarged, perspective drawing is at page 495; Fig. 1 of the patent drawings and the perspective drawing are here reproduced.

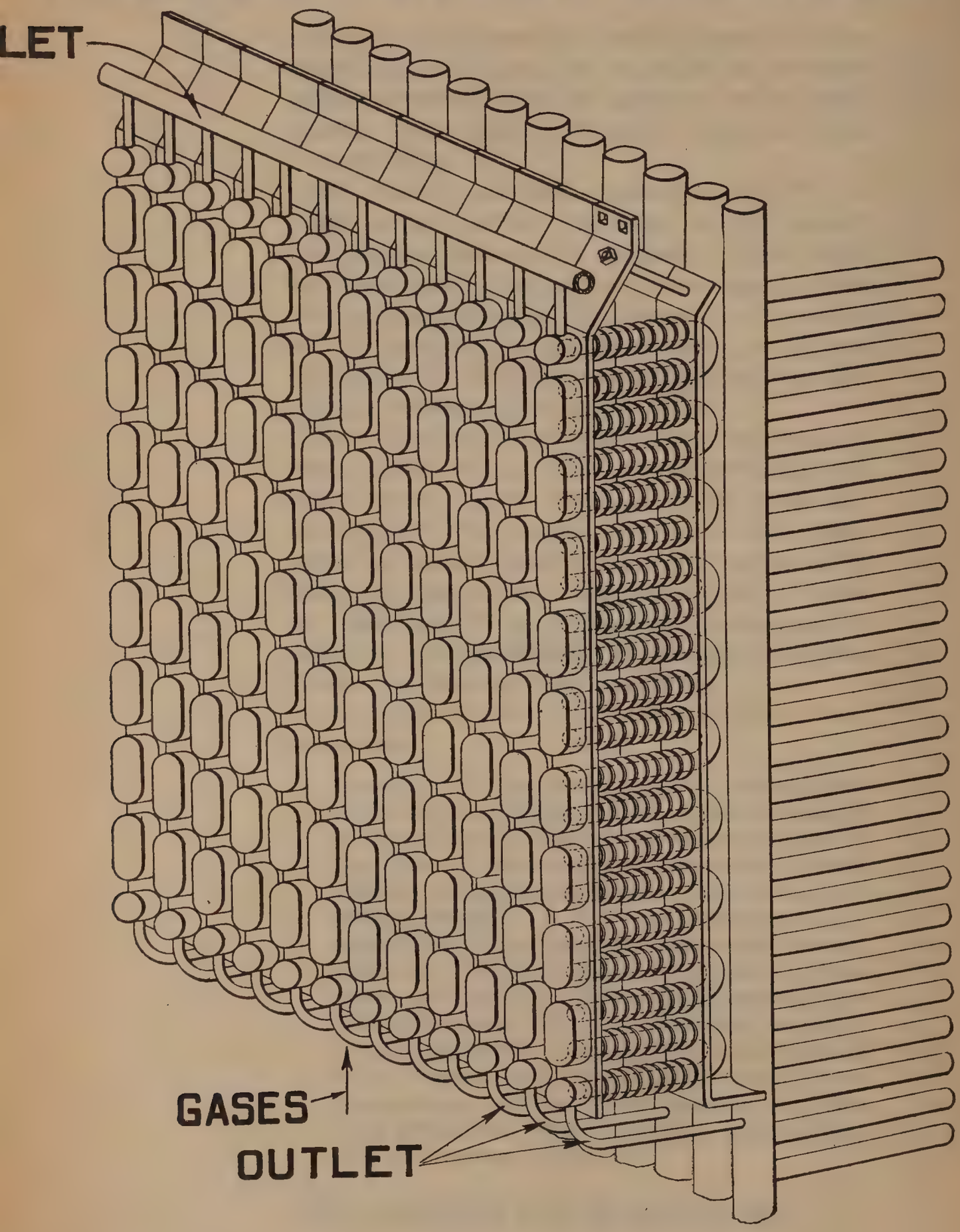
As is stated in the Foster patent, the feed water is introduced at the top of the economizer "and by aid of its gravity zigzags back and forth across and downward in the counter current to the rising gases, the highest temperature of the feed water in said economizer being at the point where it enters the boiler proper" (p. 1, lines 13-19)—just as described in the specification of the patent in suit, though the claim does not so specify.

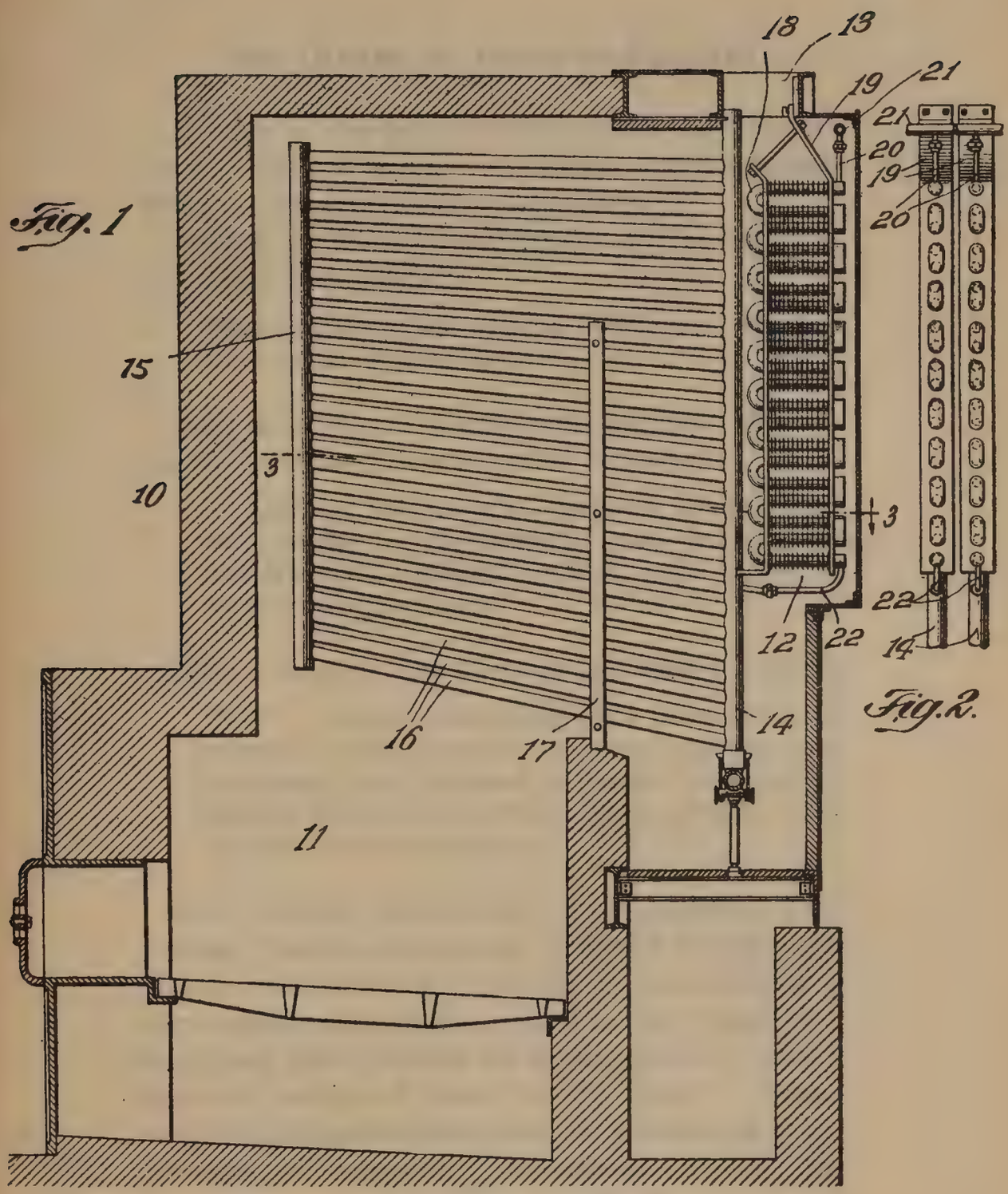
Also, Foster states (p. 1, lines 22-27, 36-44) that he employs

> "independent cast metal rings in contact with each other and fitting snugly on the economizer tubes so that the absorption of heat energy of the gases of combustion by the water flowing through the economizer tubes will be as complete as possible * * * to provide a larger contact surface between the gas and the metal, where the transference is slow, than between water and the metal where the transference is relatively rapid. Thus by providing an economizer tube with a large external as compared with internal surface, a higher efficiency or transference capacity is obtained than if ordinary cylindrical wall tubes were used, as has been the custom heretofore."

This, also, is just as in the patent in suit.

FOSTER PATENT Nº1,239,377





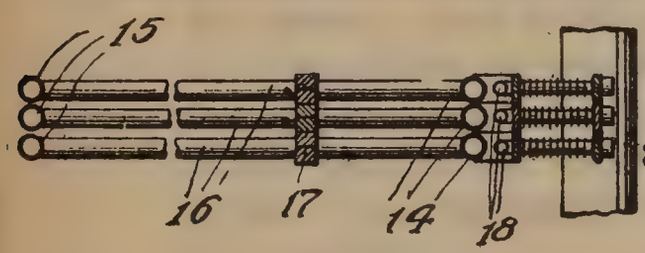


Fig. 3

Inventor
Ernest H. Foster
By his Attorney
Kerr Page Cooper & Hayward

The Claim in Issue is Invalid.

In view of the prior patents which we have discussed, claim 2 in issue is invalid. It adds no new thing or thought to what had preceded.

Taking up the various phrases of the claim in the order there stated:

> "The combination with a boiler and its furnace, of an economizer"——

This is old in all of the prior patents. According to the claim the economizer comprises

> "a bank of horizontally disposed tubes externally swept by the heating gases leaving the furnace and through which feed water is passed into the boiler," * * *

This is found in the Dietrich and Foster patents.

> "* * * said tubes being each provided with external circumferentially extending ribs proportioned and disposed to make the external surface of the tube several times greater than its internal surface area," * * *

Such was the construction of the Dietrich, Kablitz and Foster economizers. Dietrich provides the disked tubes so as to "permit the assembly of a very considerable heating surface in a small volume" and this "permits the arrangement of boilers in a very restricted space" (p. 12, *supra*). Foster uses the circumferential ribs to provide "a large external as compared with internal surface" (p. 14, *supra*). And Kablitz specifically works out the theoretically correct relation of these surfaces, and specifies that "the surface for the delivering of the heat to the water may be several times smaller" than the surface in contact with the gas (p. 13, *supra*).

The claim proceeds, with reference to the tubes:

> "* * * and being each of a length many times greater than its maximum diameter," * * *

This is obviously true of the Dietrich, Kablitz and Foster tubes. The claim does not specify just *how many* times greater the length shall be; but these three prior patents show quite a range so they meet the claim no matter what may be the definition of "many", and it may well be noted that no advantage is suggested in the patent in suit for tubes of any particular length. Whether the tubes be of the length shown in the Foster patent, or of the greater lengths of those shown in the Dietrich and Kablitz economizers, they function in exactly the same way.

Then the claim, further referring to the tubes, states:

> "* * * and being spaced to provide an external tube surface area per unit of space occupied by said bank which is several times greater than is practically possible with tubes which are of the same internal diameter and have smooth outer walls."

That is, the tubes with circumferential ribs and, therefore, having a much larger external than internal surface area, are not spaced far apart but are arranged compactly so as to get the advantage of large external surface area in a small volume or space. It is obvious that the tubes of the prior patents are so arranged, and Dietrich specifically says that

> "Such disked tubes will permit the assembly of a very considerable heating surface in a small volume and permits the arrangement of boilers in a very restricted space."

So this is what it was known that the disked tubes permitted.

And it is interesting to note that there is nothing *critical* about how many times greater is the external surface area than the internal surface area of tubes, nor about how many times the length exceeds the maximum diameter, nor about how compactly the tubes are nested. All of this is to be determined by the size and shape of the space available for the housing the economizer—that is, by the changing characteristics of steam plant design.

And steam plants *have* changed in their size, pressure and horsepower during the last twenty-five years.

It long has been and is the practice in the trade to rate boilers as 1 horsepower for each 10 feet of heating surface, this surface area being just about sufficient to evaporate 34½ pounds of water per hour from and at 212° F.; if a boiler is pushed harder so that it will evaporate more water in the same time, it still has the same rating but it is said to be operated at a percentage of its rating (Spencer, p. 94, fol. 281). Thus, a boiler rated at 100 horsepower will, if operated at 150 horsepower, be said to be operating at 150% of its rating.

Plaintiff's witness Reeve speaks of 125 horsepower boilers, with steam pressure of 60 to 80 pounds and occasionally 100 to 120 pounds, as the early practice (p. 140, fols. 418-9). As time went on, boilers grew. Ten or fifteen years ago, the average size of boiler was the 500 horsepower operated at 150% of its rating; that is, it was operated to develop 750 horsepower (Spencer, p. 94, fol. 280). Now the average size is 1000 horsepower, and 3000 is not unusual (Freeman, p. 94, fol. 282; p. 95, fol. 283).

Also steam pressures increased. In the early days the pressures used were 80 to 100 pounds. In 1906 to 1908 they had increased to 150 to 200 pounds; just before the war it was up to 250

pounds and, about 1918 to 1920, it had increased to 300, 400, 500 and 600 pounds (Freeman, p. 78, fol. 234).

Also, the boilers are operated at higher ratings than formerly. Today boilers in public utilities are operated at peak load at as high as 300%, or more, of the rating (Spencer, p. 94, fol. 280). The defendants' boiler is designed to operate normally at 200% of rating and 400% as a maximum (p. 213).

The increase of size of the boilers, increase of steam pressures and operation at well over their rating—all of which came about before the alleged invention of the patent in suit, meant several things, namely:

1. In the early days when pressures were low and boilers were of comparatively small size, the most economical economizers were those made of plain cast iron tubes. The cast iron was the best known cheap material which would withstand corrosion, and was strong enough to stand the comparatively low pressures; of course, the pressure in the economizer is at least as much as that in the steam boiler to which it is connected. Also, the amount of feed water to be heated was comparatively small so that the economizer did not have very much work to do, and the plain tubes would transfer enough heat. There were no stringent restrictions of space, so many plain tubes could be used.

2. When higher steam pressures came into use, the cast iron tubes were not strong enough, and other kinds of tubes became desirable (p. 78, fols. 232-3), as stated in the prior Foster patent (p. 7, *supra*).

3. Also, when the larger boilers came into use and they were operated at far above their rated

capacity, that meant that much more fuel must be consumed in the same period of time. That, in turn, meant that an increased volume of gases is produced in the same period and those gases must get out through the chimney. This meant, also, that more feed water had to be heated for introduction into the boiler to produce the increased steam. This brought in two things:

(*a*) space and structural limitations. The economizer must be made more efficient without proportionately increasing its total size. "The increase both in the size of the boilers and in their rate of operation has made the reduction of the economizer housing desirable" (Spencer, p. 94, fol. 280; and see plaintiff's witness, Reeve, p. 143, fol. 429). There was no longer space for indefinite multiplication of plain tubes to transfer the requisite amount of heat to the increased volume of feed water. The economizers must, therefore, be made more efficient and compact. Dietrich, Kablitz and Foster had taught how to do this by the use of circumferential discs.

(*b*) draft losses necessarily increased. More gases had to be gotten away more rapidly.

"Draft loss" refers to the suction required to draw the gases from the furnace out through the chimney. It is called a "loss" because power has to be expended to create the suction, and the power costs money. When a chimney alone is relied upon, the suction is created by the difference in weight, per unit of volume, of the air outside of the chimney and the heated gases within it; the latter, being the lighter, are sucked or pushed (as one chooses to look at it) up the chimney. If there are more gases to be handled, the chimney may be made higher so as to create more suction and thus make the gases move at a higher velocity, or the chimney may be made larger in diameter, or both. But this

is expensive and there is limit to size. So it is common, instead of attempting to use only the "natural" draft of a chimney, to use an induced draft, as by means of a fan. All this costs money.

But the suction and velocity of movement of the gases, and the consequent draft losses, had been increasing. Even as early as 1911 the draft losses were from ¾ to 2 inches (p. 88, fol. 262). In 1913 the suction and velocity had very much gone up; power must be applied and therefore losses are incurred in imparting this higher velocity of the gases and, by 1913, the draft losses *through the economizers* had gotten up to 2½ and 3 inches of water (p. 84, fol. 250). This is substantially the same as the draft losses specified in the Bell patent as "three, four or five inches of water, and of which much more than half is utilized in moving the heating gases *through the economizer*" (p. 6, lines 45-48), namely, about 2 to 3 inches.

These higher velocities of the gases, resulting in draft loss, did not injure the economizer efficiency, but increased it. Kablitz, as we have seen at page 14, *supra,* knew of the advantage of high gas velocity in economizer operation; he created such high velocity by baffles provided for this purpose.

And the defendant, the Sturtevant Company, in an installation at the Commonwealth Edison Company, in 1913, in order to increase the economizer efficiency, increased the velocity of flow of the gases through the economizer by restricting the chamber in which the economizer was placed, and had a suction of nearly 3″ of water (p. 84, fol. 250; p. 88, fol. 263).

The patent in suit was right in stating (p. 2, line 14) that the advantage of high gas velocity in economizer operation was "well known".

But this whole matter of velocity of movement of the gases and draft loss has nothing to do with claim 2 in suit. The plaintiff's expert Reeve, when

asked if an economizer having the tubes with extended surfaces arranged as specified in claim 2, would be the economizer of the patent *notwithstanding it had a low draft loss,* said that it would (p. 167, fol. 500). The plaintiff's own draft loss, through its economizer, was .05 to .10 in one typical installation; .55 to 1.31 in another, the higher losses being when the boilers were operated at higher ratings (p. 356).

The matter of draft loss comes into claim 1 (not in suit) but is not in claim 2, as plaintiff's expert admits, as we have just seen, and is not to be imported into it. See *Anderson Foundry* v. *Potts,* 108 Fed. 379 (C. C A. 7).

Claim 2 deals only with the compact, extended tube surface economizer, and sets forth nothing new.

History of the Defendant's Economizer.

The economizer used by the defendant, Connecticut Light & Power Company, is one of the many economizers developed by the Sturtevant Company (the other defendant) in over twenty-five years of practical experience in the manufacture and sale of economizers, and most of that time as the largest manufacturer of such apparatus in this country. Today it is still the largest manufacturer of cast iron economizers (p. 77, fol. 230). In 1923 it had its biggest year in this type of economizer (p. 88, fol. 263). Sturtevant economizers have been sold all over the world, although the largest part have been installed in the United States and Canada (p. 77, fol. 230).

The first economizer put out by the Sturtevant Company was of vertical cast iron tubes arranged in straight rows. In 1903 this was redesigned so that the tubes were staggered (p. 77, fol. 231). In

all these economizers cast iron was used as the material for tubes and headers in order to resist the corrosion (p. 76, fol. 227).

In 1910 the Sturtevant Company installed an economizer in the Maverick Mills in Boston, having cast iron headers and steel tubes, the latter being of special patented material called Spellerized steel, which had been developed by a man by the name of Speller, and was claimed to resist corrosion. As a matter of fact the tubes lasted only a few months and had to be replaced with cast iron (p. 77, fols. 231, 232).

Besides these vertical tube economizers the Sturtevant Company made a *horizontal* cast iron tube type "a great many years ago", and installations of this type were made in 1916 for Barrett Company, and a great many were put in service (p. 82, fols. 244-5).

As shown in the drawing, this economizer (Ex. V, p. 499) in general construction and arrangement is like the defendant's economizer except that it does not have the extended surface.

The defendant's economizer is only this earlier economizer made of steel instead of cast iron, and having the extended surface in the form of disks upon its tubes.

With the increase in pressure, to which we have referred above (p. 18), came the demand for a stronger economizer than that possible with the cast iron tube. This could be used up to 250 or 300 pounds, or even 350, but for higher pressures was not safe (p. 78, fols. 232-3).

In 1920 the Sturtevant Company sent a man abroad to determine what had been done there and to see if there was not some stainless steel or other steel that could be used and would withstand corrosion (p. 79, fol. 237).

In July, 1922, the attention of the Sturtevant Company was directed to a lead coating process

which was first suggested for use on fans and blowers, which is one of the large lines of the Sturtevant Company (p. 78, fol. 234; p. 79, fol. 238). Such fans and blowers are subject to rapid deterioration from rust and corrosion where they are handling gases from coal containing sulphur. Renewal is often necessary every two or three years.

The Sturtevant Company immediately began experimenting with lead coating to adapt it to steel tube economizers, some modification being necessary to secure the proper coating and resisting qualities. As soon as this was accomplished a steel tube economizer having plain, smooth tubes was put out (p. 80, fols. 38-9). This economizer has gone into commercial use, a great many having been sold, and just recently an installation of five of these plain tube economizers has been completed at Detroit Municipal Plant. This type of economizer was very similar, except for the fact that it did not have the extended surface, to defendant's economizer complained of as an infringement.

After the success of the lead coating had been demonstrated, Freeman gave instructions to Derry, the head of the Sturtevant economizer department, to work out an extended surface type of economizer, "as boiler and power plant designs were developing, space was being limited" (p. 80, fol. 240). For a great many years prior to this time the Sturtevant Company had used extended surface on hot blast heaters, and for the cooling of aeronautical motors which the Sturtevant Company was building during the war; and on generating sets for at least 15 years, and in drying work. Besides its use in these cases, the engineers of the Sturtevant Company were familiar with its common use on house radiators, automobile radiators, superheaters, and aerofin heaters (p. 80, fols. 240, 242).

The first experiments were with the shrunk-on ring method in which the rings were expanded by

heating, then positioned upon the tube and allowed to cool and contract. This method, however, was not satisfactory on account of the poor contact between the rings and the tube which interfered with the transference of the heat from the ring into the tube (p. 80, fols. 240, 241). Then the Sturtevant Company purchased patent rights in a method of expanding the tubes so that they fitted tightly within the disks, and this method has given the best contact of anything that has yet been found.

This method was secured in December, 1924 (p. 81, fol. 241), and the first sale of an extended surface economizer by the Sturtevant Company was in April, 1925 (p. 88, fols. 263-4).

This is the history of the defendant's economizer and it was only the natural and normal development of a concern which had been in the economizer business for over a quarter of a century, that had developed and manufactured economizers of many different designs and types, and that had produced the economizer complained of to meet the new and changing conditions of pressures and space limitations. Just as soon as a suitable protection against corrosion was secured, the engineers of that concern, using the common, every day knowledge of extended surface possessed by all engineers and taking advantage of the past experiences of their company, brought out this economizer, using a novel method of securing the disks to the tubes.

In this economizer there was nothing new (as compared with the art prior to the patent in suit) except the lead coating, supplemented by the method of attaching the disks; they are the things which are responsible for the defendant's economizer and such commercial success as it has attained.

In these economizers the defendant has taken nothing from the patent in suit.

The economizer contains, as did the economizers of the prior Dietrich and Foster patents, horizontally disposed tubes, with circumferential ribs to enlarge the outer surface area, just as in the Dietrich and Foster economizers; and the tubes are staggered as in the Kablitz economizers and as in the Sturtevant Company's own prior practice (p. 21, *supra*).

The defendant has not copied any details disclosed by the patent in suit.

Thus, the defendant's economizer is made up of a plurality of sections, each section comprising horizontal headers extending across the entire width of the economizer at the front and rear, and connected by the horizontal row of nine parallel tubes which are spaced across the entire width of the economizer. In the patent in suit there are no sections, no headers and each pipe in each horizontal row is independent of and out of connection with all the other pipes of that row.

Defendant's economizer passes all the water from one horizontal row of pipes to another horizontal row of pipes through a single return bend. The economizer of the patent passes the water from the pipes in one horizontal row to the pipes in the next horizontal row through 14 return connections in the economizer shown in Fig. 1 of the patent and through 28 return connections in the economizer shown in Fig. 7.

The extended surface on defendant's economizer is in the form of thin disks spaced along the economizer tube leaving 87½% of the tube bare and exposed to the gases as prime surface, the most efficient type of surface for heat transfer. The economizer of the patent seeks completely to cover the steel tube with the cast iron rings or sleeves, leaving no portion of the steel tube exposed.

Defendant cleans its tubes from dust and soot by means of soot blowers located in the spaces pro-

vided for that purpose between the several groups of sections which make up its economizer. The patent in suit proposes to remove soot and dirt by washing with water, no spacing apart of portions of his economizer being required.

Defendant's tubes and extended surface are protected from corrosion both internally and externally by a thin lead coating. In the patent in suit there is no protection for the tubes from internal corrosion but an attempt is made to localize the corrosion in a portion of his economizer, which portion is easily replaced (p. 2, line 112, to p. 3, line 49). It protects from external corrosion by the cast iron sleeves or disks which cover the entire tube. The prior art, as exemplified by the Foster patent, prevented corrosion by using copper, or other non-corrodible tubes. That is much more nearly the defendant's way.

And the defendant does not use the thing which the patent in suit describes as the fundamental discovery, namely, that the economizer should be made very large, with reference to the boiler (pp. 2-3, *supra*). Nor does it use the water velocity through the economizer, upon which the patent lays so much stress (p. 2, lines 121 *et seq.*).

The plaintiff makes no contention that the defendant uses these things, but only that the defendant's tubes have an external surface area 5.8 times the internal, that area being, according to plaintiff's witness, 10.47 square feet per cubic foot, whereas plain tube economizers had about 4.2 square feet per cubic foot (p. 47, fol. 140; p. 48, fol. 142).

But the prior art taught that the circumferential ribs would provide an external surface area many times that of the internal area (pp. 12-14, *supra*). And when this is done, the area per cubic foot is necessarily several times greater than when plain tubes are used, unless the ribbed tubes were

intentionally spaced far apart—and the prior patents show nothing of this sort, but quite the contrary (pp. 12-14, *supra*).

Nor is there anything unusual about the gas velocity and suction, or draft loss, used by defendant. Kablitz had pointed out the advantage of high velocity (p. 14, *supra*) and the Commonwealth Edison Company had used it in 1913 (p. 20, *supra*) and the patent in suit says that high gas velocity should be used to give efficient heat transference and that this was "well known". At the defendant's plant the draft loss varies from .26 to 3.60 inches of water as the rating at which the boiler is, at the time, operated, varies from 100% to 400% (pp. 222-3). This compares with the draft loss of between .2 and .28 which was the Kablitz draft loss in 1908 (p. 506, fol. 1517) which was in a boiler which apparently was operated at its rating; as the boiler is pushed more and more, at a higher rating, the loss goes up rapidly.

We submit that the defendant's economizer embodies only what was taught by the prior art and that the patent in suit is invalid to cover it.

The Opinion of District Court and Plaintiff's Theories.

The decision of the Court closely followed the plaintiff's theories and point of view.

The gist of the opinion is at pages 533 and 534 of the Record. The Court states (p. 533) that the patentee

> "assembled old elements in *a new organization* of parts so as to produce a more beneficial result."

If he did, his patent may well be valid. But *is* any new organization defined in claim 2?

The Court erroneously seems to have thought that there was something advantageous in a draft loss and that the patented organization of parts creates it, the Court saying that, though claim 2 does not mention draft loss (p. 534):

> "It does, however, call for an organization and arrangement of the economizer tubes which result in a draft loss—a beneficial result not obtained prior to Bell's invention."

There are several errors here. In the first place a draft loss is *not* beneficial; it means expense. If the desired flow of the gases up the stack could be secured without draft loss, that would be so much saved. Again, draft loss had always existed; it was and is low when the boilers were small and operated at low rating because, then, the volume of gases was small and there was no occasion to take them away rapidly. But the draft losses had increased, to almost the defendant's highest draft losses, as early as 1913, many years before the patent in suit. The patentee did not create them, as the Court seems to have thought.

Again, on page 534 the Court says that the defendant "is unable to point out anything in the art which discloses the principle of draft loss in the operation of an economizer". What the Court here refers to as the "principle of draft loss" is undoubtedly what the Court expressed on the preceding page of the opinion (p. 533) as follows:

> "He recognized that high draft resistance in the passage or flue leading to the stack or chimney of a boiler,—always recognized prior to his invention as a waste,—could be converted into a profitable investment. Appreciating that the rate of heat transmission to the economizer tubes varies proportionately with the velocity of the flow of the hot waste gases over the tube surfaces, Bell made the discovery that, by combining extended surface tubes with the closest possible spacing of such tubes, a

> close rubbing contact of gases on metal and consequently a high rate of transmission, as well as high draft loss, would be produced. Bell accepted this loss because he appreciated that with his structure there is developed an increase in the rate of heat transmission which more than compensates for the draft loss. He realized that the provision of extended surface tubes alone would not be sufficient and that the compacted heating surface, so arranged and disposed and spaced that it obstructs the draft, results in a highly efficient economizer."

The "principle of draft loss in the operation of an economizer", therefore, to which the Court refers is that, when the gases pass at a high velocity, the heat transference is the most efficient; and that a "compacted heating surface, so arranged and disposed and spaced that it obstructs the draft, results in a highly efficient economizer."

But the principle that, when gases move at high velocity, the heat transference to the surface over which they pass is most efficient was "well known", as the patent admits (p. 2, line 14). And its applicability to and use in economizers was also known, as described by Kablitz and as used by the Commonwealth Edison Company (p. 20, *supra*).

And high velocity of movement of the gases, resulting in high draft loss through the economizer, had become the established thing in steam plant operation prior to the patent in suit (p. 20, *supra*). When anyone then placed an economizer in the path of these gases moving at high velocity, the principle of most efficient heat transference, due to such high velocity, was necessarily utilized irrespective of whether or not the economizer was compactly made.

The basic errors in the decision of the Court were in considering that no one operated at a high draft loss until Bell taught them to do so, and that Bell created such loss and utilized it. These funda-

mental propositions are contrary to the proofs, as we read them.

As already pointed out (*supra,* p. 17) there is nothing in the claim which fixes any critical value for the ratio of external to internal surface or for the ratio of external surface to unit of space occupied, but, so far as can be determined from the drawings of the prior patents, these ratios in the Dietrich, Kablitz, and Foster ribbed tube economizers are substantially the same in numerical value as for plaintiff's and defendant's economizers. (See Chart, Deft.'s Exhibit BB, Rec. p. 525.)

We submit that the defendant had a right to use the extended surface tubes of Dietrich, Kablitz and Foster in the modern boiler plants, created prior to Bell's invention, which had the high velocity of movement of the gases.

Respectfully submitted,

Charles Neave,
Alfred H. Hildreth,
Melvin R. Jenney,
of Counsel for Appellant.

W1665

United States Circuit Court of Appeals,

SECOND CIRCUIT.

POWER SPECIALTY COMPANY,

Plaintiff-Appellee,

vs.

THE CONNECTICUT LIGHT & POWER COMPANY,

AND

B. F. STURTEVANT COMPANY,

Defendants-Appellants.

BRIEF ON BEHALF OF PLAINTIFF-APPELLEE.

January, 1929.

WILLIAM G. McKNIGHT,

Of Counsel for Plaintiff-Appellee.

The Evening Post Job Printing Office, Inc., 154 Fulton St., New York, N. Y.

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United States Circuit Court of Appeals,

SECOND CIRCUIT.

POWER SPECIALTY COMPANY,
Plaintiff-Appellee,

vs.

THE CONNECTICUT LIGHT & POWER COMPANY,

and

B. F. STURTEVANT COMPANY,
Defendants-Appellants.

BRIEF ON BEHALF OF PLAINTIFF-APPELLEE.

This appeal by the defendants is from a decree by Judge Thomas adjudicating the validity and infringement of claim two of Letters Patent No. 1,565,305, granted to the plaintiff in 1925, upon application of John E. Bell filed in 1922, covering an economizer for use in steam generating plants. The decree is at page 18, the opinion at page 531, and the patent in suit at pages 170 to 183, of the Record.

An economizer is a device for abstracting heat from the waste gases of a furnace, and thereby increasing the temperature of the feed water before it enters the boiler.

The economizer invented by Bell and first given to the world in 1922 was at that date a *new* article of manufacture and is covered by claim two as follows:

> "The combination with a boiler and its furnace, of an economizer comprising a bank of

horizontally disposed tubes externally swept by the heating gases leaving the furnace and through which feed water is passed into the boiler, said tubes being each provided with external circumferentially extending ribs proportioned and disposed to make the external surface area of the tube several times greater than its internal surface area, and being each of a length many times greater than its maximum diameter, and *being spaced to provide an external tube surface area per unit of space occupied by said bank which is several times greater than is practically possible with tubes which are of the same internal diameter and have smooth outer walls.*"

By italics we emphasize that portion of the claim which constitutes Bell's brilliant and revolutionary discovery and produces a *new* organization of elements producing a new and beneficial result. The tubes are to be so spaced with reference to each other, as to crowd, into *a unit* of space occupied by the tube bank, the largest possible area of external tube surface,—the *spacing* is to be such as to produce the ultimate in *compactness.* Bell was the first in the economizer art to recognize that high draft resistance, always theretofore recognized as a waste, could be converted into a profitable investment. Appreciating that the rate of heat transmission varies proportionately with the velocity of flow of the gas over the tube surface, Bell made the discovery that by combining *extended surface tubes* with the *closest possible spacing* of such tubes, he would produce a "tortuous gas path" resulting in close rubbing contact of gases on metal, and a consequent high rate of heat transmission, and also high draft loss. Bell accepted this loss because he appreciated, as none before had, that with his structure there is developed an increase in the rate of heat transmission which more than compensated for the draft loss. The provision of extended surface tubes alone would not be sufficient, as erroneously argued by the appellants. It is the combination as Bell first suggested, of the extended heating surface tubes with the close spacing of such tubes

which does the trick and which constitutes Bell's great contribution to the economizer art.

For thirty years before Bell's disclosure, the Green economizer was substantially the only one in commercial use. It was an enormous affair; the vertical cast iron water tubes were *four to six* inches internal diameter; they were spaced far apart; they were provided with external scrapers to remove soot from the external surfaces; the gases were admitted at the side or end and travelled lazily to the flue; the *draft loss* was slight, comparatively insignificant. The definite teaching of the art, prior to Bell, was *wide apart* spacing of the tubes and *small* draft loss. Any considerable draft loss *was* regarded as an intolerable waste, and as stated by Prof. Marks, one of the defendant's experts "an unmitigated evil" (R. 105), and yet during this period economizer conditions altered materially, resulting in vast changes in steam engineering practices. In the early days, coal was cheap, plenty of space was available, boiler pressures were low, units were small,—mechanical stokers, draft-fans and steam turbines were unknown. It was difficult to introduce the economizer—it was hard to justify its initial cost and maintenance cost in terms of heat, and hence fuel, saved. It was still more difficult to justify its draft resistance. As time went on the price of fuel increased, boiler pressures increased and space became more valuable, and the economizer was more extensively used. Whereas, in the eighties a boiler pressure of eighty pounds was high, in 1922 when Bell entered this field, boiler pressures had arisen to 250 and 350 pounds. The price of fuel had increased, and space in which to locate the economizer became increasingly scarce and expensive.

In this state of the actual, practical and commercial economizer art, Bell came forward with his revolutionary disclosure. He told the art to "face right about". He said, incur a high draft loss, but do it in my particular way, and convert that loss into a profitable investment. And so Bell for the first time instructed the art to utilize

extended surface water tubes, horizontally mounted, and *so spaced* from each other vertically and horizontally as "to provide an external tube surface area *per unit of space occupied* by the bank of tubes several times greater than is practically possible with tubes having the same internal diameter and with smooth outer walls". This extreme compactness was of importance quite aside from the saving of space for the plant as a whole, important as that was. It was the compactness within the *economizer casing itself* which accomplished what Bell sought, —namely, *a usefully increased draft resistance.*

Bell's invention went immediately into commercial use, and an entirely new and useful economizer was made available to the power plant public. It was a *new article* of manufacture. The plaintiff has built up a considerable industry at large and continuing expense under the Bell patent which was acquired by the plaintiff under an agreement obligating it to pay, during the term of the patent, two and two-thirds per cent of the sales price of economizers f. o. b. plaintiff's shops (R. 113) and in accordance with that agreement the plaintiff has already paid out in royalties, for the use of this invention, about Eighty thousand ($80,000) Dollars. The patent is only two years old and for the balance of the term, the plaintiff is obligated to pay a very large sum. Between May, 1921 and November, 1927, the plaintiff sold 340 economizer units, embodying the Bell invention, comprising 1,869,058 square feet of tube surface, receiving therefor $4,439,270, with a net profit to it of $585,411 (R. 113). Installations of the Bell economizer, which for trade reasons (R. 113) the plaintiff has named "Foster Economizer", were made in 1921. The device was fully described in its bulletin (Defendant's Exhibit A, R. 237) printed and distributed in 1922 and a model exhibited at the Power Show in the same year (R. 112). Immediately, the Bell invention was recognized as a useful and efficient device, and met with instant approval. Indeed, where *the space available for the installation of an economizer is limited,* the Bell economizer is the *only* one

which can be used, and at the same time secure the area of external tube surface per unit of space occupied by the tube bank, which is possible with the Bell device.

A situation of such great substance should not, and will not, be destroyed except upon a conclusive showing that it is without real merit. No such showing has been made by the appellants. *Infringement is admitted.* There is no anticipation. Counsel for the appellants do not assert that there is, but attempt to justify this bold appropriation of the plaintiff's invention by erroneously asserting that claim two of Bell, is for "a structure in which there was nothing new" and is invalid as "it adds no new thing or thought to what had preceded" (Appellant's Brief, pp. 12, 15).

Counsel rely upon the Deitrich French patent of 1894, the Kablitz German publication of 1908, and the Foster U. S. patent 1,239,377 of 1917, and assert that these patents show "prior economizers with tubes having ribs". Of course they do. We admit, as Bell does in his patent, that tubes having ribs to provide extended heating surface, were old prior to Bell. That is, *lineal extension* of heating surface, was old.

Neither of the references relied upon discloses or even intimates the *close spacing* of such tubes "to provide an external tube surface area *per unit* of space occupied" by the tube bank, which is greater than is practically possible with tubes having smooth outer walls. That is a vastly different matter from mere *lineal* extension of the individual tube surface. It is the close spacing of such extended surface tubes so as to crowd into a *unit of space occupied,* as much heating surface as possible, which imports novelty into the Bell claim and renders it a *new* organization producing a new result.

But counsel, realizing that there is in these prior references, no written description of Bell's close spacing, gratuitously assert that they see such arrangement in *the drawings* of these patents. It is easy now, perhaps, long after the grant of the Bell patent and when driven to

the necessity of justifying appropriation of the plaintiff's invention, to see close spacing in these pictures, although unaccompanied by any suggestion, in the description accompanying them, of such arrangement of the tubes. But in 1894, 1908 and 1917 when each of these prior disclosures was made, and each must be tested in the light of the teachings of the art on those respective dates, no one familiar with the economizer art would have dreamed of close spacing of these tubes. On the contrary, *wide open* spacing would have been resorted to, because that was the practice, and for the reason that it was ingrained in the minds of the economizer public that high draft loss was "an unmitigated evil". The best proof of this is, that neither Deitrich, nor Kablitz, nor Foster made any impression upon the art, neither led toward Bell and it remained for the latter, and the plaintiff working under him, to give this valuable invention to the public.

The value of the Bell patent must be preserved to the plaintiff unless it appear that its invalidity has been established by clear and convincing proofs. No such proofs exist. There is no anticipation. Patentable novelty is clearly proven by the evidence. If any doubt exists, which we deny, that doubt must be resolved in favor of the patent. The defendant seeks to justify its appropriation of this valuable invention by asserting that Bell's work was not new, but we submit that the actualities in economizer manufacture and use,—not "prophetic suggestions" dug out of the archives of forgotten things, and mere pictures at that,—should be controlling, and when the history of the commercial, actual use of economizers, before and after Bell's advent, is given proper weight, the conclusion is inevitable that Bell not only made an invention, but one of great and substantial merit.

We shall now refer to the patent in suit and see exactly what the invention is which has had this remarkable success.

The Bell Patent in Suit.

The specification is long, necessarily so, because there are a number of features of invention not covered by claim two, but set forth in the other seven claims. Counsel for the appellants, in their discussion of the Bell patent (Brief, pp. 2-12), deal with and emphasize these *other* features,—"beneficial results" and functions—and substantially ignore the real subject matter of claim two—the usual procedure where the effort is to divert attention from, and to avoid, the issue.

We shall endeavor in the following discussion to direct particular attention to those portions of the specification which deal with the constituent parts of, and the structure of, the economizer defined by the claim.

Fig. 1 (R. 170) shows the general organization of a steam generating plant. At the bottom is the furnace consisting of two mechanical stokers feeding in coal from right and left. Above the furnace is the combustion chamber A^1 in which the gases are completely burned. The boiler tubes B^3 are near the top of the chamber and inclined. The steam superheater tubes C are seen just above the boiler. A gas flue A^2 leads out of the chamber A^1 to the exhaust fan G. Located near the top of this flue is the economizer D. The hot furnace gases from the chamber A^1 are diverted by the baffle plates upwardly to the left through the boiler tubes near the left end, then move to the right over the superheater tubes C, then, because of the baffle plate B^8, they are forced downward across the tubes and striking the baffle B^7 they are forced to the right under the lower edge of baffle B^8, and up through the furnace outlet A^2 and through the economizer tubes D^1 to the exhaust fan.

The specification, referring to the inventor's objects and aims, states (p. 1, lines 9-82, R. 175):

> "The general object of my invention is to provide improvements in method of, and apparatus for generating steam. More specifically the ob-

ject of my invention is to provide for the more effective utilization of an economizer for transfering heat to boiler feed water from the partially cooled products of combustion leaving the boiler furnace.

It has long been common practice to preheat boiler feed water by the use of an economizer, but heretofore the economizer has ordinarily been regarded as an adjunct of the boiler, which, while of value, is distinctly of secondary importance as compared with the boiler proper. I have discovered, however, that highly beneficial results, both with respect to the thermal efficiency and operating economy of a steam generating plant, and with respect to the initial construction and maintenance costs, may be obtained by making the economizer a more important element of the steam generating plant than has heretofore been the case.

To this end I substantially increase the ratio of economizer heating surface to boiler heating surface over that heretofore employed in commercial practice, and provide the economizer heating surface in an economizer of special construction characterized by *its* **compactness** *and requiring a draft much stronger than is required in the types of economizers heretofore in use to move the heating gases through it.* In the preferred practical mode of carrying out my invention I employ economizer tubes similar in construction to those heretofore employed in the well known Foster superheater, in that each tube comprises an inner tube of wrought steel which is surrounded by an externally corrugated tubular cast iron casing. In the economizer which I employ, the special tubes are preferably *spaced closely enough together to give an aggregate external tube surface area* **per unit of volume of space occupied** *which is several times greater than is obtained or is practically possible of attainment in economizers of the types heretofore in commercial use.* The compactness of the economizer which I employ not only reduces the bulk and initial cost of the economizer but makes it practically feasible to enclose the economizer in a housing which forms part of the

boiler setting and is sufficiently air tight to practically eliminate air leakage into the economizer, notwithstanding the high draft suction impressed on the economizer.

Coming now to the construction of the tubes and their arrangement and disposition in the headers and casing to produce the complete economizer, we will first direct attention to Fig. 6 (R. 174), showing the tube to comprise the inner tube *d*, which is of steel, and the outer casing of cast iron discs d^1.

The Bell specification gives specific directions as to the relative areas of external and internal heating surfaces of the tubes, the disposition of the tubes relative to each other, and the close spacing so as to realize the ultimate in compactness, as follows (p. 5, lines 56 to 98; R. 179):

"This heat absorbing capacity is of course greatly enhanced by the relatively great amount of external heating surface in contact with the furnace gases which it provides. *The area of external gas swept heating surface of each tube may advantageously be in the neighborhood of* 5½ to 6½ *times as great as in the internal wet surface area of the tube.*

In the construction shown in Figs 1 and 2 the externally corrugated economizer tubes D′ are arranged in horizontal rows which extend transversely to the general direction of gas flow past them, and are also arranged in rows extending parallel to the general direction of gas flow, the tubes in the adjacent horizontal or transverse rows being staggered. *The tubes D′ are closely spaced.* In ordinary practice I prefer to make the average of the distances between the centers of each tube D′ and the centers of the immediately adjacent tubes about *one and one quarter times the maximum tube diameter.* Notwithstanding the small space between the exterior surfaces of the economizer tubes, the internal tubular parts *d* are sufficiently far apart to permit the ready use of suitable end connec-

tions between the different tubes, since these connections are external to the inner metal shell D^2 of the economizer housing, and the tube casing *d'* need not project through the shell D^2. *With this spacing the external heat absorbing surface of the economizer* **per unit of space occupied** *by the bank of economizer tubes is several times greater than is practically possible with economizer tubes of the same internal diameter and having smooth external walls,* especially since with the smooth walled tubes the minimum distance between the tubes is limited by the necessity for providing space for the necessary end connections to the tubes."

Having now made clear what the structure of the economizer is to be, the patentee sums up, and clearly emphasizes the manner in which the close spacing of the tubes contributes to close rubbing contact between gas and the surface of the tubes, resulting in a high rate of heat transmission, as follows (p. 6, lines 11 to 48, R. 180):

"*The close spacing* of the economizer tubes, and their corrugated exterior surfaces *provide tortuous gas paths* through which the heating gases move *with relatively high velocity* thus insuring a high heat transmission factor and a large economizer capacity per unit of volume. The consequent comparatively small economizer volume required for a given duty makes it practically feasible to employ an economizer housing which is substantially air tight, thus *practically eliminating air leakage into the economizer* notwithstanding the comparatively *high draft suction* required to move the heating gases through the boiler and economizer. Air leakage is objectionable both because of the cooling effect of the air leaking in, and also because of the resultant increase in volume of the gases which must be handled by the draft creating fan. Air leakage tending to increase the exhaust fan capacity required is especially objectionable in the practice of my invention because the relative high draft suction which I ordinarily employ requires a considerable expenditure of fan

> driving energy at normal load even when there is no leakage at all. It has heretofore been the practice to operate a boiler plant comprising an economizer with a draft suction which ordinarily does not exceed one and three-quarter inches of water, at a maximum. In proceeding in accordance with the present invention I may advantageously employ a draft suction at normal load as high as three, four, or five inches of water, and of which much more than half is utilized in moving the heating gases through the economizer."

We will now show to the Court just what *lineal extension* of tube heating surface *plus* Bell's *close spacing* means as compared with the closest possible spacing of tubes of the same internal diameter and with smooth outer walls. We will compare the defendant's infringing economizer with another built by the defendant, Sturtevant Company, in which the tubes have smooth outer walls. The foundation facts as to dimensions of defendant's infringing device were admitted by stipulation (R. 28, 29), and as to the smooth surface tube economizer were given by plaintiff's witness Keenan (R. 44-46) and not questioned by the defendants.

In the infringing device the "external tube surface area *per unit* of space occupied" is 10.47 square feet, whereas in the Sturtevant non-infringing device it is only 4.19 square feet (R. 45, 48).

Appellants assert (Brief, p. 17) that there is "nothing critical" about how "compactly the tubes are nested". What was "practically possible" with tubes of the same internal diameter and with smooth outer walls was shown by plaintiff's witness Keenan (R. pp. 44-46). Babcock & Wilcox best was 4.22 and the defendant, Sturtevant, was 4.19 square feet of heating surface *per unit volume* of space occupied. And yet, when this Sturtevant Company was driven to infringe the Bell patent, using extended surface tubes, *closely spaced,* its economizer has 10.47 square feet per unit of volume of space occupied,—which is "several times" greater than what was "prac-

tically possible" with their smooth surface tube economizer. So it certainly is "critical' both with respect to the claim and with respect to the actualities in economizer design.

It is not *alone* lineal extension of heating surface of the tubes, as appellants' counsel would have this Court believe, but it is that *combined with the close spacing* of the tubes, clearly set forth by Bell, which realizes the startling improvement set forth above. That combination was Bell's contribution. It is nowhere set forth or even hinted at in the prior patents discussed in appellants' brief. It was a bold conception. The commercial art prior to Bell taught wide apart spacing of the tubes, because draft loss was considered an evil and waste. Bell told the art to "right about face", accept the draft loss, but follow his instructions as to close spacing of extended surface tubes and convert that loss into a profitable investment.

The Prior Art Merely Emphasizes the Importance of Bell's Achievement.

The contention of the appellants appears to be, that in view of the prior patents, claim two of the Bell patent is invalid, because it "sets forth nothing new," the defense usually employed when, as here, there is no *real* defense. We welcome the opportunity to discuss these prior patents, for taken in connection with the history of economizer manufacture and use in this country, these patents show that what Bell accomplished did amount to invention—the structure defined by claim two *is new.* He succeeded where others failed, making a revolutionary improvement, which the prior patents did not suggest to those most closely in touch with this art.

It is interesting and significant to realize that appellants rely upon three patents for economizers, and the earliest, Dietrich, was of 1894 in France. During the twenty-eight years which elapsed, between Dietrich and

the appearance of Bell in 1922, came Kablitz in 1908 and Foster 1,239,377 in 1917, and yet the disclosures of these patents had not the slightest effect in this country upon the commercial practice in economizers—the cost iron tube economizer remained the only type in commercial use, and *it persisted substantially unchanged.*

The Dietrich French Patent of 1894.

In this patent (Defendant's Exhibit H, R. 435-443) Fig. 3 shows an economizer and is alone pertinent to this controversy. It shows horizontal tubes provided with discs, and of these the text states (Defendant's Exhibit I, R. 445):

> "Such disked tubes will permit the assembly of a very considerable heating surface in a small volume and permits the arrangement of *boilers* in very restricted space."

That is all,—simply a disclosure of discs upon tubes extending *lineally* the external heating surface as compared with the internal surface of the tube, and Dietrich made this suggestion for an "arrangement of *boilers*". The essence of his invention was the combination of small round discs and large square discs. The latter being for the purpose of directing the gases and protecting the joints at the end of the tubes from excessive heat (R. 446). In this case the more important consideration is what Dietrich *did not* disclose—the text does not disclose *any dimensions* of the tubes, nor any disclosure or suggestion of that *close spacing* of tubes which is necessary to a realization of Bell's invention—no suggestion of that *principle of construction* which is so clearly defined in claim two of the Bell patent, and which results in large increase of heating surface *per unit of volume* of space occupied by the tube bank, for the purpose of obstructing the draft. Not only is the specification of Dietrich silent on this most important matter, but the claim is for something wholly remote from the combination of Bell—the Dietrich claim covers merely the disked tubes and the

"special large discs" for directing the flow of the gases, and protecting the ends of the tubes (R. 447). The situation as to Dietrich is so well stated by Professor Reeve, that we can do not better than adopt his thoughts, as follows (R. 146-149):

> "The question as to Dietrich is, What is its disclosures in terms of what was known in 1894?
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> The Dietrich patent has been emphasized as showing most thoroughly the idea of a compact economizer with extended surfaces on the tubes and as if that constituted an anticipation of Bell's disclosure in 1922. I can not see it at all in that light. Dietrich does not disclose any desirability of compactness. He has a drawing which shows a form of flue and a form of economizer space in which space is wasted. That is, aside from the tubes themselves, there is no suggestion of any economy of space. Dietrich did not have at all before him that problem which began to confront the engineers in 1921 or 1922. The demand of the modern highly developed central station power plant boiler has lately been for a compact economizer.
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> He simply was showing a convenient form of economizer, as he thought, and he recommends it because he says it provides more heating surface. Like all these other inventors, he does not say more heating surface in terms of what. If he had done so, he would have brought home to his own mind the fact that the Dietrich economizer, as is a fact, was not an improvement upon the old Green. Its history shows that. It was merely what was then a more expensive form of the old Green. It could not have scrapers, as all economizers had had up to that time, because of the ribs. It was not cheaper to build, because while we can now build heating surface cheaper with gills or discs than without, that was not true at that time.
>
> And so the history of the Dietrich economizer proved exactly what I think the face of the paper shows, and that is that it was a suggestion for a modification of the old Green economizer which was not an improvement at all, but was a step

backwards. It not only did not lead to any further use of Dietrich economizers, but it did not lead a step toward the Bell disc tube economizer of 28 years later."

Certainly Dietrich did not *disclose* the invention defined by claim two of Bell.

The Kablitz German Publications of 1908.

With reference to the Kablitz articles in the German publications (Defendant's Exhibits X (R. 503) and Z (R. 509) and their translations Y (R. 505) and AA (R. 517) we direct the attention of the Court to Professor Reeve's remarks on this topic (R. 148-151).

"Turning now to the Kablitz economizer, and referring first to the 1912 article, because on page 1742 there appears an assembled drawing of the plant in which Kablitz erected his economizer, and which gives us an excellent idea of the task which he had in mind.

Here is a large plant of horizontal shell boilers, ten of them, leading into one of these large horizontal underground flues which were common in Continental practice. This flue leads off to a vertical stack at the right-hand of the figure.

In a small portion of that huge flue Kablitz has erected, or more properly has suspended, a series of economizer tubes. There is no faintest suggestion in the entire plant of any economy of space. The flue is enormous. There is apparently some 15 or 20 feet of space between the boiler house and the stack which was needlessly there. That is, needlessly from the American point of view. The whole thing is wanton in its consumption of space.

Kablitz himself makes no mention of compactness as a recommendation for his structure. He merely points out that it [economizer] does save some waste heat and that it is not the objectionable feature which economizers were then commonly regarded, because, as he urges at two different places, any tube which beaks down can

be removed during the noon hour without interfering with the operation of the boilers.

He does speak of his discs on his tubes as increasing the heating surface. That was obvious. All engineers knew that heating surface could be increased by placing discs on pipes. But he does not mention any reason for that. He does not say in what terms they would constitute a gain. He does not say whether they will save space or save materials.

In other words, Kablitz was not at all in competition with the smooth tube economizer, nor was he meeting users whose objection to economizers was that they did not have room for them.

He was appealing to a public where the engineer of the big plants did not believe in economizers at all. The engineers did not believe that they would win enough heat to pay for the interference with operation which was due to broken pipes and all that.

Then, again, as to the question of draft obstruction which enters into the topic of compactness, I need to correct Professor Marks' testimony on that point. Professor Marks mentioned on page 193 of the record that Kablitz draft was two-tenths to twenty-eight hundredths of an inch of water. Professor Marks at that time was referring to the 1908 article, and the 1908 article makes no mention whatever of draft.*

The 1912 article does make a statement as to the draft, stating that it is four to five millimeters. Four to five millimeters are not equivalent to two-tenths or twenty-eight hundredths. Their equivalent in inches is 0.157 for the smaller figure or 0.197 for the higher figure. That is to say, Kablitz's draft resistance was to vary from a little over one-seventh of an inch to a little less than one-fifth of an inch, the average

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* This statement was corrected by Prof. Reeve (R. 165) as follows:

"I was in error in stating that the Kablitz 1908 article, Defendant's Exhibits X and Y, did not make any mention of draft loss. It does show and state a higher draft loss than the 1912 article which I quoted. The draft loss given in this 1908 article is 5 to 7 millimeters, which is .275 inches."

of which figures is about one-sixth of an inch. Compare that with the statement in the Bell patent that he proposes to use 3, 4 or 5 inches. That is at page 6, line 45. We see what a tremendous contrast there was between Kablitz and Bell.

Kablitz was in the attitude which was stereotyped throughout all those forty years, of apologizing for his economizer and insisting that it took very little draft indeed, because all the engineers had at their disposal merely a fixed amount of draft, and if they installed economizers the boilers got that much less draft, because of the interference of the economizer, and so the problem always was, can the economizer save as much as it costs in draft?

Kablitz shows his recognition of that fact, and his argument is that his economizer does save as much as it costs in draft because it costs very little in draft.

That is the direct opposite to Bell's whole position. Bell says, 'Build your economizer so that your draft resistance deliberately goes up to 3, 4, or 5 inches,' which is from 20 to 30 times Kablitz's draft. Then Bell explains, 'If you do this in the certain way which I have advised, you will find it profitable.'

That was rank heresy according to all standard engineering thought up to that time. We have before us hardly a statement more pertinent of that standard position than this very Kablitz disclosure."

Kablitz U. S. Patent of 1908.

This patent (Defendant's Exhibit D, R. 411) shows an economizer comprising *vertical* tubes provided with ribs or discs. These tubes are hung from a rectangular shaped horizontally disposed header. The header has a number of cleaning openings F^1 to F^5 and the water tubes B^1 to B^{14} are "grouped about the several openings F^1 to F^5 inclusive so that when a cleaning device is inserted through any one of said openings it will be in close proximity with the exterior portions of a plurality of

pipes thereby greatly facilitating the cleaning operation" (p. 1, lines 99-106, R. 415).

And it was that feature of grouping of a plurality of ribbed tubes around cleaning openings which Kablitz emphasized as his invention, as shown, for instance by claim one, as follows (R. 416):

> "A feed water heater comprising in combination, a body structure provided with a plurality of cleaning openings and a plurality of pipe connecting channels, by-passes connecting said channels and a plurality of ribbed pipes or tubes connected with each other and secured to said body structure in communication with said channels, the disposition of said pipes being such that a plurality thereof are closely grouped about each opening."

What Kablitz *did not* disclose is that *principle of construction* which distinguished Bell from all his predecessors—that is, the *close spacing* of extended surface tubes in the manner set forth in claim two of Bell. As shown in Fig. 5 of Kablitz (Plaintiff's Exhibit 14, R. 287) which illustrates the tubes arranged in the form of a chess board, with tubes located on the black squares and the white squares left vacant, Kablitz made no effort to occupy more than half of the available space with tubes (R. 151, 152).

The appellants did not mention this patent. We refer to it because it shows what Kablitz *patented,* and it was something very remote from what counsel pretends, at this late date, to see in the Kablitz publication drawings.

The Foster Patent of 1917.

In 1917 Foster took patent 1,239,377 (Defendant's Exhibit E, R. 425) for a fuel economizer, again utilizing Foster's extended surface tubes. The patent shows two sections of tubes which are stubby and short as compared with the diameter of the discs upon the tubes. Here Foster was dealing with counter-flow and remov-

ability of tube sections, as shown by claim one as follows (R. 428):

> "A boiler having a plurality of individual boiler sections comprising headers and boiler tubes connecting said headers and also having a vertical passage for the furnace gases beyond said section, in combination with an economizer composed of a plurality of individual sections vertically arranged in said passage and installed between the boiler and smoke stack, the tubes of said economizer being vertically arranged with respect to the flow of the furnace gases and the inlet and outlet to said economizer being at the top and bottom respectively, whereby water circulates by aid of its own gravity through said economizer, said economizer sections being individually connected to said boiler sections whereby one boiler section and one economizer section may be removed for repair or replace ment without disturbing the other sections."

This Foster patent was cited by the Patent Office, and claim two of Bell was finally allowed over it. In the prosecution of the Bell application, his attorney said (Plaintiff's Exhibit 16, p. 27, line 18, R. 314; p. 40, line 5, R. 324):

> "The Foster patent No. 1,239,377 does not meet the terms of any of applicant's claims and shows a structure which would not give the characteristic advantages and results of applicant's constructions, and is principally interesting as showing how non-obvious it was to use Foster corrugated elements in the proper manner to achieve the results secured by the applicant. The economizer of this Foster patent was designed in accordance with the teaching of the practical prior art that an economizer could not be used with advantage unless it involved but a trifling draft loss."

Page 40, line 5, R. 324:

> "The length of the economizer tubes shown in the Foster patent No. 1,239,377, is not many times the tube diameter as specified in appli-

> cant's claim 2, and there is not the slightest suggestion in the Foster patent of Mr. Bell's bold conception of greatly increasing the amount of heating surface in a cubic foot of space occupied. On the contrary, the economizer of the Foster patent apparently followed the current practice of the prior art of intentionally spacing economizer tubes so openly that the economizer would not materially increase the draft requirements of the boiler furnace with which it was associated.

It will be recalled that claim two of Bell defines the tube as being "of a length *many* times greater than its maximum diameter". Defendant's expert Browne and appellants' counsel seem troubled about the meaning of the word "many". This quotation from the file history of the Bell patent makes the matter perfectly clear. Bell's tube is some 30 times longer than its maximum diameter —or "many" times, as compared with the tube of the Foster patent 1,239,377, which is about 5 or 6 times longer than its maximum diameter.

Summary of Prior Art Patents.

From all of the patents relied upon, the appellants quote one short sentence only from the Dietrich patent in support of their assertion that *close spacing* of extended surface tubes was not new with Bell. That one sentence referred to *boilers* and not to economizers, and *it meant only more heating surface per lineal foot;*—it does not mean, and cannot be construed to mean, more heating surface per unit of volume.

Counsel at this late date, long after the grant of the Bell patent, profess to see in the drawings of these prior patents the characteristic Bell close spacing. But in 1894, 1908 and 1917 when these patents were published the teachings of the art were such that these drawings would have conveyed quite another and different notion. The economizer public was imbued with the definite teaching of *wide open spacing* of tubes and insignificant

draft losses. The mere suggestion of close spacing and high draft loss would have been discarded as rank heresy. As defendant's expert Marks said "draft loss is an unmitigated evil"—that was the attitude of the entire economizer public prior to 1922 when the Bell invention was first made public.

Dietrich, Kablitz and Foster show water tubes provided with discs to extend the heating surface per *lineal* foot, relatively to the large diameter smooth surface tubes of the Green economizer, standard at their respective dates. Neither *described* close spacing to provide additional surface *per unit volume* of space occupied.

It was Dietrich's object, by use of his large square discs, to direct the flow of gases and protect the ends of the tubes. It was Kablitz' object to group his tubes around a plurality of openings to facilitate cleaning the tubes, and in so doing he occupied only half of the available space with tubes. It was Foster's object to connect economizer sections individually to boiler sections, whereby a section may be removed without disturbing other sections.

Neither of these patents made the slightest impression upon the commercial art—the old Green economizer persisted substantially unchanged during all those years.

Appellants' assertion that the drawings of Dietrich, Kablitz and Foster show close spacing is a gratuitous and voluntered assumption, which violates the definite teachings at the dates of their respective publications, namely, 1894, 1908 and 1917. Upon those dates the art knew only wide open spacing, necessitating insignificantly small draft loss—any considerable draft loss was regarded as "an unmitigated evil".

In addition to the above general statements, applicable and fatal to each reference, Kablitz shows *vertical* tubes, and not horizontal tubes as specified in claim two, and Foster shows short tubes and not tubes of "a length *many* times greater than its maximum diameter."

Claim Two of the Bell Patent Is Valid.

Appellants do not assert that claim two is anticipated. We propose to show that it is not, for in doing so we will answer, in part, the appellants' other assertion that claim two is invalid 'because it is not new". If claim two is not anticipated, it, being for a combination of separate elements *organized* in a certain defined way, must, as an organization or combination, be new.

In the law relating to patents, the doctrine is firmly established, that a prior patent, to constitute an anticipation, must contain a disclosure of the defined invention in such clear and exact language as to enable a person skilled in the art to practice the invention.

> *Scoville Mfg. Co.* v. *Satler,* 21 F. (2nd) 630.
> *Marr* v. *Hardinge,* 20 F. (2d) 241;
> *Forchheimer* v. *Franc* (dissenting opinion of Denison, *C. J.*) 20 F. (2d) 553, 556;
> *Galvin* v. *Emerson,* 19 F. (2d) 885;
> *Babcock & Wilcox* v. *Springfield,* 16 F. (2d) 964.

There is no patent relied upon in this case which can, by any stretch of the imagination, be considered anticipation when tested in the light of these doctrines.

Bell, the patentee of the patent in suit, taught and reiterated throughout his patent, high draft loss and hence high velocity of the gases, and a definite *principle of construction,* whereby the draft loss shall be converted into a profitable investment. Bell's principle of construction, contemplating very close spacing of tubes and resulting in extreme compactness, is clearly set forth in claim two of the patent in suit. The prior commercial art, on the other hand, consistently taught low draft loss, —regarding any such loss as an evil to be avoided—and wide open spacing of tubes permitting a lazy slow flow of gases.

The defendant's expert Browne failed to meet the

issue. When comparing claim two of the patent in suit with the alleged disclosures of the prior art patents, he does not once assert that the precise combination as set forth in that claim is found in any prior patent, and the farthest he went, when considering the last clause of the claim, was to assert that this, that or the other prior patent, shows a construction in which necessarily there is "a much greater area of heating surface than there would be if only plain tubes were employed".

Browne here entirely misses the point. An increase in heating-surface does not necessarily constitute an improvement in the art. Professor Reeve has made it plain (R. 141-143) that heating-surface, *per se,* is inherently just as unmitigated a waste as Professor Marks characterizes draft-loss. The whole question is: does the increase in heating-surface suggested *justify itself*—and if so, how—in terms of first cost, space occupied, coal saved, or the like? As to this the Bell patent is specific and clear, for he says that when the extended surface tubes are closely spaced, the resulting economizer structure will be so compact as to obstruct the draft, but the loss in this respect will be more than compensated for in the increased rate of heat transfer. Appellants assert (Brief, p. 21) that Professor Reeve said that the structure of claim 2 of Bell would embody the invention "notwithstanding it had a low draft loss," but Reeve added that it would be "a poor embodiment of the Bell patent" (R. 167).

So the disclosures noted by Browne in the prior patents are not enough. There must not only be that close spacing of tubes and profitable compactness which was new with Bell, but that feature must be found in the specification of the patent in clear and unmistakable language. But that is not the case, for Browne admits (R. 74) that the Foster patent does not mention in any way any close spacing, nor any particular spacing, of the tubes, nor anything as to the employment of high draft suction. And this is true of all the other patents relied upon. Not one single word on the subject of the close spacing of the tubes, which is the all important matter.

So the appellants are driven to, and do, rely merely upon the pictures of these prior patents. This is an important and significant fact in connection with the defense of this case. There is literally not one statement in all the prior art relied upon, which even suggests the use of *close spacing* of extended surface tubes in the manner specified by Bell and for the purpose of converting a high draft loss into a profitable investment.

But mere drawings, even if they incidentally show arrangements similar to that illustrated and described in the patent in suit, but not essential to the first invention, nor designed, adapted nor used to perform the function performed by the second invention, and especially where the first patent contains no suggestion of the result sought to be accomplished by the second invention, cannot in any sense be considered as an anticipation. This doctrine was announced by the Circuit Court of Appeals in this Circuit in *Mosler* v. *Lurie,* 209 F. 364.

Assuming that the drawings of prior patents show—though they do not—the arrangement of Bell, we have shown that when the drawings are considered in the light of the *claimed* invention, such arrangement was not essential to the first invention. So we submit, that a valuable patent is not to be destroyed upon the showing of mere drawings. It is easy now, after Bell disclosed his invention to the world, to see some resemblance in these prior drawings. But who is to say that before Bell, any person skilled in this art, would have recognized in these drawings the characteristic Bell close spacing of tubes, in combination with the other features of claim two? The fact that neither Dietrich, nor Foster, nor Kablitz, made any impression upon the art, shows conclusively that these drawings conveyed no information to those skilled in the art, as to Bell's achievement. In fact, the fixed teaching of the art at the effective date of each of these patents was wide open spacing and insignificant draft loss. Appreciating that high draft loss was "an unmitigated evil", no one in building an economizer under either of these patents would have dreamed of close spacing.

The dangerous and uncertain perplexities surrounding reliance upon mere drawings is well illustrated in this case. It results in pure speculation. In an effort to make the best showing possible, and ignoring the facts as to the actual commercial art of the time, defendants' Expert, Professor Marks, assumes tubes of one and seven-eighths inch diameter in the *pictures* of the Dietrich French patent. Yet this record shows that in 1894 there were no economizer tubes of 1⅞ inch diameter and that, as a *commercial operation,* it is not *practicably possible* to cast tubes, with or without discs, of 1⅞ inch diameter (R. 128, 146); and further that to make a Dietrich economizer of such dimensions as that would be to construct a mere toy. The Dietrich patent—and all other prior patents—must be interpreted in the light of the state of the art at the date of its publication. The defense in this case, however, interprets the prior art patents in view of the teachings of the economizer art of today—*after* the Bell contribution.

We submit that the invention defined by claim two of the patent in suit is not anticipated. Professor Reeve stated the matter correctly when he said (R. 158, 159):

> "There has been no disclosure entered whatever which combines the horizontal gilled tubes, closely spaced and staggered in such a way as to develop compactness and draft resistance, as the primary aims in design, with the other incidents to the claim as they may appear.
>
> We have before us merely a series of disclosures which might be argued, by a stretch of the imagination, to be aggregable into something like Bell, but in each case we not only have to bring together elements which are, according to the analysis which I have already given, incompatible and which have not been associated in the past, but we have to bring together those elements distorted. There is not a disclosure before us which would make a good modern economizer, unless it were deliberately distorted in large degree.
>
> I have brought out how Prof. Marks had to distort the Dietrich, in order to make it even

superficially like a modern economizer, and that this distortion has been proven by the given engineering testimony to have been impractical. My point is not merely that it was impractical, but it was vain, and even if we distort Dietrich to the extent that Prof. Marks stated, we would not then have a useful modern economizer. We would not even have an economizer better than the old cast iron economizer.

The same thing is true of Kablitz, that we could not make a Kablitz economizer which would be of any use whatsoever in a modern central station power plant unless we distorted the disclosure of the patent, and the commercial article beyond any scope of the patent."

The rules of law as to anticipation are much more stringent with respect to foreign language patents and publications. In *Permutit* v. *Wadham,* 13 F. (2d) 454 (6th C. C. A.), that experienced patent Judge, Denison, *C. J.,* said with reference to foreign patents (p. 456):

"We cannot give any effective force to this oral testimony. Not only was plaintiff left at a disadvantage in not being prepared to meet such unexpected proofs, where the hearing was in Detroit and all the data were in Germany, but neither earlier invention by others than Gans in Germany or earlier use by any one in Germany, is of any importance in a suit upon a United States patent. Nothing of earlier date in Germany and unpatented there invalidates the patent unless it was a publication; and the rule is firmly established that *an earlier foreign language publication must be clear and explicit in the extreme.*

Such publications cannot be effectively supplemented by proof that foreign devices which are now said to be the embodiments of the publications were actually constructed at the time and did successfully perform. Such proof is self-destructive. There can be no need for it unless upon the theory that the actual construction shows precisely what was intended by the published description and, if the description is ambiguous enough to need this kind of support, it is fatally deficient."

On the same topic, in *Simplex* v. *Hamilton,* 21 F. (2d) 196, Judge Campbell said (199):

> "The Carr Lockwood patent is a foreign reference, and must be taken for exactly what it shows on its face, and cannot be reconstructed to anticipate the patent in suit. *Permutit Co.* v. *Harvey Laundry Co.* (C. C. A.) 279 F. 713; *Westinghouse Airbrake Co.* v. *Great Northern Ry. Co.* (C. C. A.) 88 F. 258."

In view of what we have already said with reference to the Dietrich French patent, the Foster patent, and the Kablitz articles, showing as we have that neither contains any language upon the all important matter of tube spacing, and that the defense relies merely upon pictures, we submit that they are not "clear and explicit in the extreme" and should not be considered.

Bell's Work Constituted Invention.

The plaintiff, operating under the Bell patent, was the first to manufacture a horizontally disposed, extended surface tube economizer, in which the tubes are so closely spaced as to provide great compactness, and more tube surface area per unit of space occupied than had been practically possible with tubes of the same diameter and having smooth exterior walls. That was a new and distinct type of economizer. Where the space available for the installation of an economizer is limited, the Bell economizer is the only one which can be installed and secure an equal amount of tube surface area. In modern central station power plants, located usually in cities and places of congested population and consequent high land values, such space is always limited. The smooth wall tube economizers of the Sturtevant and Bobcock & Wilcox cannot compete with the Foster economizer when space available is the controlling factor. This fact was made clear by plaintiff's witness, Shoudy (R. 126-128), at the Amsterdam plant, where he was the

Engineer and rejected Sturtevant and Babcock & Wilcox smooth tube economizers and installed a Bell extended surface tube economizer, for the reason that the economizer must be placed in a certain location with limited space, and the Bell could be used and the others could not. And plaintiff's witness, Dowd, has told us of the dilemma of the New York Steam plant; how it had a very limited space for economizers, and to get the required capacity the Bell was the only type that could be used (R. fol. 341, p. 114). This was also the situation at Hell Gate (R. fol. 341, p. 114).

We have, heretofore, referred to the popularity of the Bell invention as amply attested by the large and growing sales of Bell economizers by the plaintiff—between 1921 and November, 1927, 340 economizers having 1,869,000 square feet of heating surface, for which plaintiff received $4,439,000 with a net profit of $585,000 (R. 113).

Babcock & Wilcox Company has not offered extended surface tube economizers in competition with the plaintiff. Where its bare tube economizer cannot compete, that company has accepted the inevitable. The Green Fuel Economizer Company once bid on a job in competition with the plaintiff and offered extended surface tube economizers; but upon being notified by the plaintiff of its Bell patent, The Green Company withdrew from that contract and has not since competed (R. fol. 342, p. 114). Not so the B. F. Sturtevant Company. It has offered extended surfact tube economizers in competition with the plaintiff's economizer, and by underbidding the plaintiff, secured the contract for the Devon plant admitted to infringe in this suit. It has been successful in underbidding the plaintiff in other instances (R. fol. 340, p. 114). And this Sturtevant Company has attested to the novelty and usefulness of the Bell invention in its Bulletin No. 334 (Plaintiff's Exhibit No. 4, R. 197), published in 1925, for it there described its extended surface tube economizer in language strangely similar to that used by the plaintiff in its Bulletin (Defendant's Exhibit

A, R. 327) published three years earlier—in 1922—wherein is described the Bell or, as now commercially known, Foster economizer. It is too apparent that the Sturtevant Company seeks to destroy the value of the plaintiff's patent and to capture a part of its business, and to justify itself by asserting that what Bell did was "not new".

That this defense fails, and should fail, is evident when we compare the remarkable history of Bell's achievement with the commercial state of the economizer art prior to Bell.

In Professor Reeve and Shoudy taken together we have a continuity of practical experience with the use of economizers covering a period of about 40 years—about 35 years prior to the advent of Bell in 1922 and five years thereafter. And in determining the question of invention or patentable novelty the best test is the condition of the art before and after the appearance of the invention in question. On this point the 2nd Circuit Court of Appeals, by Judge Learned Hand, has aptly stated the matter in *Dubilier Co.* v. *New York Coil Co.*, 20 F. (2d) 723, as follows (724):

> "Van Deventer's condenser may, if one choose, be regarded as no more than a *more compact form* of Dubilier's. He left out one of the rivets and used the casing as a terminal of opposite polarity. Nevertheless this required an internal rearrangement of the condenser itself, and, while his notion and its execution may seem obvious, we cannot say that it was inevitably within the powers of the ordinary journeyman. Suppose the proof should be that Dubilier's condenser was at once superseded by Van Deventer's, because the art especially needed a condenser of as small size as possible. Must we say that the man who eliminated one rivet and used the casing in its place made no invention? In all *inventions the safest test is the condition of the art before and after the putative invention appears.* At least that is an immeasurably safer test, when available, than any *a priori* conclu-

sions as to what is or is not an obvious step. To the last we should not resort, except in cases of absolute necessity."

And again the same Court speaking through Judge L. Hand, in *H. C. White Co.* v. *Converse Co.,* 20 F. (2d) 311, said (313):

> "Again and again, *ad nauseam,* courts have been fond of saying that it is the obvious when discovered and put to use that most often proves invention. *In such matters we look rather to history than to our own powers of divination, if history is at hand.* Kirsch *v.* Gould, 6 F. (2d) 793 (C. C. A. 2). Children have not changed, and would have liked as well to push about astride a little tricycle 200 years ago as today. The means have been also always at hand. The end and the means having therefore been for long available, this inventor merely thought to unite them by a fortunate insight which had theretofore escaped the imagination of others. We see in this an invention just because, being so simple, it had not occurred to any one before. The fact that the changes were so slight is quite irrelevant, so long as they were essential to the purpose, as they were. While the statute grants monopolies only for new structures, and not for new uses, invention is not to be gauged by the necessary physical changes, so long as there are some, *but by the directing conception which alone can beget them. Traitel* v. *Hungerford,* 18 F. (2d) 66 (C. C. A. 2). That was certainly absent before it came to White's mind."

We have already reviewed the history of the Bell device after its advent in 1922. Let us now consider briefly the state of the art before Bell. It is established definitely that for at least 35 years prior to Bell, the only economizer in general commercial use was the cast iron vertical tube type, having four inch tubes, provided with scrapers, with the tubes widely spaced, and the gases moving lazily over the surface of the tubes and the water also flowing slowly through them.

In the early days when economizers were used at all, the chimney was relied upon to produce the draft through the furnace, boilers and economizers. It was the heat in the chimney which developed the draft and the draft suction was very slight. Later, suction fans were utilized to create an induced draft, but here again the draft suction was slight, because any considerable draft loss was recognized as a waste and unless the draft loss was kept down, the first cost and maintenance cost of the fan could not be justified.

The large cast iron tube economizer with small draft suction existed, substantially unchanged, from the early days down to the time of Bell's invention. But during that time, central station power plant practices changed in numerous ways. These changes, important and radical as they were, had no substantial effect whatever upon the design or operating conditions or use of the cast iron economizer. The first notable change was in the furnace —mechanical stokers were substituted for hand fired furnaces—resulting in better consumption of fuel and gases and a higher heat in the combustion chamber, and in the practicability of much larger units of power. Boiler pressures increased. Whereas in the early days, of which Professor Reeve had personal knowledge, boiler pressures were usually less than 100 pounds, by 1916 such pressures had been increased to 200 and 300 pounds. This fact had a significant influence upon the economizer situation. The increased boiler pressure required an increase in the water pressure necessary to drive the water through the economizer to the boiler, and engineers began to question whether the cast iron tube economizer was any longer suited to these increased pressures. So we hear from plaintiff's witness, Shoudy, that in 1916 engineers no longer considered the cast iron economizer suitable for these increased pressures, and they ceased to recommend its use for central station power plants.

The price of coal had its influence. As its price increased, there was a greater incentive for saving, and so the use of the economizer was considered more favor-

ably. The question of space became of vital importance. Whereas in the early days power plants were scattered in various sections of a town or city, in later days these power plants had been centralized into one great power producing station, located usually, in cities where the cost of land is high. Even where these limitations did not apply, the economizer must perforce fit in between a boiler below, and the fan and stack above, having their foundations many feet up in the air. Therefore engineers came to feel that the great, bulky, large cast iron tube economizer could not, from the standpoint of space available alone, justify itself.

That then was the condition of the art at the time Bell made his invention. Bell was a well-known, experienced engineer. He had wide experience and had for many years been employed by the Power Specialty Company as its consulting engineer. Prior to that time, he had been associated with Babcock & Wilcox. He recognized the situation, and instead of attempting an improvement upon the then existing commercial type of economizer, Bell scrapped all of the preconceived ideas with reference to the structure of the economizer itself, and the operating conditions of its practical use. He selected for his tube the well-known Foster extended surface tube. But that was not all nor enough to meet his desired end. Bell decided to use tubes of a length many times greater than the maximum diameter of the tube. He decided to mount these tubes horizontally and to stagger them with relation to each other. Bell told the art, as aptly stated by Professor Reeve, to "right about face" with respect to draft suction and compactness. He deliberately recommended what every engineer previously to Bell had feared and avoided, namely: he recommended a high draft loss, so that he would cause the gases to pass through the economizer at high velocity in a tortuous path; because he recognized that he could thereby increase the rate of heat transference from the gases to the exterior surface of the tube, and from the surface of the tube to the water within. He specified

that his tubes should be so spaced as to "provide an external tube surface area per unit of space occupied by said bank which is several times greater than is practically possible with tubes which are of the same internal diameter and have smooth outer walls". He recognized that by this expedient he could and would produce an economizer structure having such extreme compactness that with the high velocity of the gases, there would be that intimate, rubbing contact between gases and surface of tubes which would greatly improve the rate of heat transference. By this expedient he was able to turn an "unmitigated evil" in the form of high draft loss, into a profitable investment. Bell thereby created an entirely new economizer structure, he did it at a time when there was nothing in the practical, commercial art anything like Bell's device.

In the patented art relied upon by the defendant, we find the best evidence of the novelty of Bell's device, and that his work rose to the dignity of invention. Dietrich in 1894, Kablitz in 1908, Foster in 1917; each suggested the use, in an economizer, of extended surface tubes. But none of these prior inventors had the slightest conception of accepting the high draft loss, or any idea of how such a loss could be made profitable. So far as concerns the disclosures in the texts of any of these prior patents, there is no intimation of that close spacing of tubes which is the characteristic new feature of Bell, and which, in connection with the other features of his invention, constitutes Bell's means for converting the high draft loss which he deliberately incurs into something that was profitable. Foster, an engineer connected with the Power Specialty Company, to which his patents were assigned, was, and had been for years, familiar with the use of extended surface tubes; and yet he recognized and accepted the teaching of the art with respect to draft loss. So far as his patents reveal, he had not the vision to see that the high draft loss could be profitably utilized. He never dreamed of that expedient which was successfully resorted to by Bell, also connected with the plaintiff.

The Second Circuit Court of Appeals in *Babcock & Wilcox* v. *Springfield Company,* 16 F. (2d) 964, held valid and infringed a patent to Bell for a superheater boiler and it appears from the opinion of the court that the Bell claims, held valid in that suit, defined combinations of old and well known elements. The court said (p. 966):

> "It was the peak loads, increased as the demand for electric power advanced, that caused engineers at this time to attempt to fill the demand for bigger and higher units and higher superheats. Bell designed a higher boiler with an unusual number of rows of water tubes, and increased correspondingly the amount of coal burned by adopting full fire in place of half firing. He relocated the superheater from its old position in the triangular space above the tubes down into the interdeck position between the banks, and thus *attained compactness of the entire boiler and superheater without increasing the setting.*"

This is sufficient to show that what Bell did in connection with the invention before the court in that case, is along the same lines as his work in connection with the invention involved in the instant case—except that in the latter, Bell's work seems to us to be of a higher order.

In the Springfield boiler case, the defendant asserted the same defenses as are relied upon here and as to invention, and lack of invention, the Circuit Court of Appeals said (p. 969):

> "A device relied upon for anticipation is not sufficient, if it requires modifications to make it accomplish that which is to be performed by the patent in suit. It may not be redesigned, even by its maker, so as to make it adaptable for the performance of functions accomplished by the new invention. *Topliff* v. *Topliff,* 145 U. S. 161, 12 S. Ct. 825, 36 L. Ed. 658.
>
> It is argued that the Bell patent is limited to the rebuilding of the boiler and obtaining uniform velocity of gas flow and that the appellees'

> boiler does not infringe for this reason. In all water tube boilers, the gases contract as they cool in imparting part of their heat to the tubes and the water or emulsion therein. The claims in suit should not be limited to a uniform velocity of the gases. The novelty of the invention here lay in the new combination of elements, each of which was old, by producing a new result and such a limitation would not make the claims more patentable."

We have precisely the same situation here. The novelty of Bell's invention lies in the "new combination of elements"; but in the instant case, Bell's invention resides in the combination of old elements plus an absolutely new element, to wit, the close spacing of his tubes. In the Springfield boiler case, however, the court held Bell's claim valid, although each of the elements in the combinaton was old, the whole being new, "producing a new result".

In view of this remarkable history of the Bell invention and its instant acceptation by the trade, and of the development of a large industry under the inspiration of that invention, the assertion that Bell's work did not amount to invention, or that the patent does not exhibit patentable novelty, will not seem sound or convincing to the unbiased and unprejudiced mind. The language of the Supreme Court in *Diamond Co.* v. *Consolidated Co.,* 220 U. S. 428, 31 Sup. Ct. 444, 55 L. Ed. 527, is conclusive:

> "Knowledge after the event is always easy and problems once solved present no difficulties, indeed may be represented as never having had any, and expert witnesses may be brought forward to say that the new thing which seemed to have eluded the search of the world was always ready at hand and easy to be seen by a merely skillful attention. But the law has other tests of the invention than subtle conjectures of what might have been seen and yet was not. It regards a change as evidence of novelty, the acceptance and utility of change as a further evidence, even as demonstration."

The Appellants Position is Unsound.

Counsel for the Appellants, in their discussion of, and quotation from, the Bell patent (Brief, 2-10) emphasize the "beneficial results" incident to the use of the economizer defined by claim two and the functional operations of the device, and then complain that (Brief, 10-12) these features are "lost sight of in the claim".

We have placed the emphasis where it belongs (*supra,* pp. 7-12)—upon the structure defined by claim two. The beneficial results and functions are important certainly, but they have no place in a properly drawn claim. A radically new article of manufacture, an economizer never before in commercial use, is defined by claim two. It is the combination of water tubes the heating surface of which is extended per *lineal* foot and the close spacing of such tubes to provide more surface *per unit, of volume* of space occupied, which with two other features specified, constitutes the new and novel organization. It is that compact structure, which requires a high draft suction, but the use of which results in the many "beneficial results" so clearly set forth in the Bell patent; it is that compact structure, which produces 10.47 square feet of heating surface per cubic foot of space occupied as against 4.19 in an economizer comprising smooth surface tubes of the same internal diameter; it is that compactness, which makes it possible to use the Bell structure where space is limited and where the smooth surface tube economizer cannot be used; it is that compact structure, which causes high draft loss, but which, because of less initial cost per square foot and higher efficiency of operation, converts that loss into a profitable investment; it is that compactness, which is nowhere found in the prior art and which was novel with Bell.

Counsel have expended much effort to show that water tubes, provided with discs or gills to *lineally* extend the heating surface, were old. That was unnecessary —it is admitted. But they say (Brief, p. 5) "this seems

to mean merely that the patentee proposes to use the old Foster tubes close together, and thus make a compact structure; but this was old, as we shall see"; and then in an attempt to justify this conclusion they say (Brief, p. 13) as to Deitrich that it is apparent from the "patent drawings that the tubes are as near together as they can be without having the flanges actually in contact"; and as to Kablitz illustration (Brief, p. 13) that the tubes "are arranged very close together". But neither Deitrich nor Kablitz *describe* the tubes as being close together. The assumption of counsel that the drawings show close spacing, ignores the teachings of the art at the dates of publication of these references, and is therefore gratuitous and volunteered.

In 1894 at Deitrich's time, and 1908 at Kablitz's time the art knew only wide open spacing of large smooth surface tubes and insignificant drafts loss. The record is clear on these matters. Prof. Marks, a witness for the defendants, calls "draft loss an unmitigated evil." He was expressing a state of mind of those familiar with economizers prior to Bell—the accepted teachings from practical experience. Prof. Reeve for the plaintiff agrees, and from his knowledge acquired over 35 years of practical experience with the economizer art, states unequivocally that during all of that period prior to Bell, the Green economizer was the only one in use and that draft loss was regarded as a waste and evil. Counsel for appellants attempt to change the complexion of this matter by referring to the testimony of Freeman, an officer of the defendant, Sturtevant Company, a highly interested witness, and they assert (Brief, p. 20) "the draft losses *through the economizers* had gotten up to 2½ and 3 inches of water," wishing it to be inferred that this was common practice. That is not true and there is no justification for it in Freeman's testimony. He was referring only to isolated instances and he does not say, with respect to such instances, that the draft loss was compensated for in other directions, so that it was converted into a gain. He nowhere in his testimony met

this issue and stated that high draft losses were common practice, nor did he deny the statements of Marks and Reeve that they were regarded as a waste and evil.

And it must be remembered that counsel are relying upon the testimony of Freeman, who stated (R. 90, fol. 268) that "the first information I had of the Foster economizer was in February, 1925." Such a statement is incredible, in view of the fact that Freeman was an executive of Sturtevant Company, and that the economizer of the Bell patent was, in 1922, fully described in the plaintiff's Bulletin (Deft.'s Ex. A, R. 327) and exhibited at the Power show in New York. The plaintiff and defendant were in close competition. Freeman must have known of the Bell economizer. If he did not, he was a careless executive and his testimony is unreliable.

Attempt is made to minimize and make light of Bell's close spacing and counsel say (Brief, p. 3):

> "Of course the economizer, whether large or small, whether with widely spaced tubes or compactly arranged tubes, obstructs the passage in which it is placed between the furnace and the stack. If it is small, that obstruction in not great, and the gases are not much retarded in their passage to the stack, so substantially no stronger draft is required to carry the gases through the economizer."

This is exceedingly misleading. There is no "of course" about it. In the Green economizer, which was large, the tubes were "*widely* spaced", so widely that the flue space for passage of the gases was enormous and designedly so, in order that no obstruction be offered to the passage of the gases; and *the larger the economizer the larger the flue area, and the lower the draft resistance.* Prior to Bell there was literally not a single instance in the commercial art in which the *economizer itself,* whether large or small, was built compactly and deliberately placed so as to obstruct the gas passage. Bell reversed the old standard practice, by using a *large* economizer and *at the same time* closely spacing its

tubes so as to make its resistance greater than that of a small economizer.

Appellants' brief, page 7, returns to the same misleading position and states "otherwise the same volume of gas could not get through the smaller hole". But THE HOLE WAS NOT SMALLER. The gas-passages in the old Green economizer were larger than where there was no economizer at all. At that date economizers could not be sold unless this were so; for the buyers were sceptical as to the value of an economizer anyhow, and if it used up any appreciable portion of their treasured little chimney-drafts—often as low as ¼ inch, where Bell speaks of 3 to 5 inches—then the use of an economizer would be rejected.

Bell, in other words, altered the economizer from the position of a serf begging permission to live, into that of a free man, demanding his rights because he pays his way.

Bell's discovery was predicated upon a change which had come gradually into the power-development field, the significance of which Bell alone noticed. This was the use of *higher steam-pressures.* With higher steam-pressure the boiler-temperature goes up automatically. With higher boiler-temperatures the flue-gases have to be thrown away at higher temperatures, because there must be a certain temperature-difference between steam and gases, in order to promote the heat-flow from one to the other with sufficient rapidity to pay for the heating-surface involved.

This is where lay Bell's discovery. As boiler-pressures went up, boiler-temperatures also went up. BUT FEED-WATER TEMPERATURES DID NOT. Hence, as boiler-pressures rose, the job of getting the water from feed-temperature to boiling-point grew greater, while that of making steam out of it grew less, both relatively and absolutely. This fact immediately offered profit in increasing the heat-transfer capacity of the economizer, while decreasing that of the boiler.

But merely to increase the *size* of the old Green type,

relatively to the boiler, would not accomplish this end; for that would merely let the gases slip past the economizer more easily than before—and so, while incurring the extra cost of the larger economizer, would turn the gases loose into the stack with *less* heat abstracted, rather than more. In order to utilize this opportunity offered by the higher steam-pressures you must make of your economizer a *heat-trap.* You must not merely provide more surface, but you must do so in a manner exactly the reverse from what, up to that time, had been standard practise. That is, you must deliberately introduce resistance, where previous practise had been to minimize resistance.

To do this, a number of different geometric forms might be suggested, all of which would be operative in the sense of obstructing the flow and abstracting the heat. But only Bell's was operative in the sense of doing these things in such a way as to *pay for the extra cost involved.* That, to the commercial engineer, was *Bell's* discovery. Bell's invention is defined by claim two, which is a *heat trap,* and justifies itself in first cost and savings effected in operation. HEATING-SURFACE COSTS MONEY. The prior inventors harp upon the provision of "more surface" as if the problem were how to build more surface. But that is no difficulty at all. Anyone can do that. All the geometrical rules for getting more surface have long been well know. The trouble is to make the greater heating-surface *pay for itself.* In what form, and in what place, can it do this?

Answer to Appellants' History of Defendants' Economizer.

The appellants discuss (Brief, pp. 21-27) the so-called history of defendant's economizer, presumably to show how easy and simple and logical were the steps leading to its bold appropriation of the plaintiff's invention.

Our reading of that discussion leaves no such impression. On the contrary it impresses us as showing quite clearly (*a*) a number of stumbling efforts and failures; (*b*) an effort to meet the plaintiff's competition by building the X type economizer having smooth surface tubes with the closest possible spacing; and (*c*) although the Sturtevant Company was, long prior to Bell, familiar with extended surface tubes it did not occur to them to use such tubes in an economizer and to closely space such tubes; and (*d*) then after the appearance of the Bell economizer the Sturtevant Company was driven to infringe the plaintiff's patent.

The District Court was Right and its Decree Should be Affirmed.

With respect to Bell's invention and claim 2 covering that invention Judge Thomas said in his opinion (R. p. 533):

> "Bell was an engineer in this art for a number of years and was fully aware of the actual and practical economizer art and of the prior patents relating to it as well as the general state of the art and had taken out various patents relating to steam engines. In the patent in suit he assembled old elements in a new organization of parts so as to produce a more beneficial result. He recognized that high draft resistance in the passage or flue leading to the stack or chimney of a boiler,—could be converted into a profitable investment. Appreciating that the rate of heat transmission to the economizer tubes varies proportionately with the velocity of the flow of the hot waste gases over the tube surfaces, Bell made the discovery that, by combining extended surface tubes with the closest possible spacing of such tubes, a close rubbing contact of gases on metal and consequently a high rate of transmission, as well as high draft loss, would be produced. Bell accepted this loss because he appreciated that with his structure there is developed an increase in the rate of heat transmission

> which more than compensates for the draft loss. He realized that the provision of extended surface tubes alone would not be sufficient and that the compacted heating surface, so arranged and disposed and spaced that it obstructs the draft, results in a highly efficient economizer."

We submit that this is an intelligent and absolutely correct conclusion with respect to the Bell patent in suit in the light of the facts developed at the trial and disclosed fully by us in this brief.

Appellant's counsel attempt (Brief, pp. 27 to 30) to show that Judge Thomas was in error in several particulars. For instance counsel quoted an isolated sentence from the opinion (p. 534) as follows:

> "It does, however, call for an organization and arrangement of the economizer tubes which result in a draft loss,—a beneficial result not obtained prior to Bell's invention."

Counsel then asserts that there are several errors here and say a draft loss is not beneficial. Of course it is not and Judge Thomas did not say that it was nor can his opinion as a whole be said to intimate any such statement. Furthermore "a beneficial result" as used by Judge Thomas does not refer to *draft loss* but to the "organization and arrangement of economizer tubes" and as Judge Thomas had before stated "Bell accepted" the draft loss for the reason that Bell's structure was such that it developed an enormous increase in heat transmission which more than compensated for the draft loss. Nor did Judge Thomas say nor intimate that Bell was the first to discover draft loss. Counsel refers to Judge Thomas' statement to the effect that Bell "assembled old elements in a new organization of parts so as to produce a more beneficial result" and then counsel make the significant statement "if he did his patent may well be valid. But *is any* new organization defined in claim 2?"

We submit that we have clearly shown that there is not

found either in the practical commercial economizer art nor in the foreign language patent of Dietrich nor in the publication of Kablitz, any description of the combination of elements defined by claim 2 of Bell. There is nowhere found in any of the patented art relied upon by the appellants that *combination* of extended surface tubes *with* that characteristic Bell close spacing of such tubes in order to provide "an external tube surface area per unit of space occupied by said bank which is several times greater than is practically possible with tubes which are of the same internal diameter and have smooth outer walls". That was new with Bell. It was a brilliant discovery. It was put into immediate practical use by the plaintiff. After an effort on the part of the defendant, Sturtevant Company, to avoid the use of such structure, that concern was driven, in order to meet plaintiff's competition to boldly appropriate the Bell invention. And to the extent of the combination defined by claim 2 Sturtevant Company *did copy* the plaintiff's invention.

Conclusion.

We submit, for all reasons set forth above, that the District Court was correct in its decision and that the decree entered by it should be affirmed with costs to the appellee.

Respectfully submitted,

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Of Counsel for Plaintiff-Appellee.

Dated, New York, January, 1929.

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